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GEOLOGICAL SURVEY BRANCH
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MEMOIR No. 10

AN INSTRUMENTAL SURVEY OF THE SHORE-LINES OF THE EXTINCT LAKES ALGONQUIN AND NIPISSING IN SOUTHWESTERN ONTARIO

BY

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To R. W. Brock, Esq.,
Director Geological Survey,
Department of Mines.

Sir,—I beg to submit the following memoir on an instrumental survey of the shorelines of the extinct lakes Algonquin and Nipissing, in southern Ontario.

I have the honour to be, sir,
Your obedient servant,

(Signed) J. W. GOLDTHWAIT.

January 17, 1910.

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INTRODUCTORY.

Nature of the Work.

In the summer of 1908 the writer was engaged to carry on an instrumental survey of certain raised beaches and terraces in southwestern Ontario. This work formed part of a more comprehensive study of the glacial and lacustrine features of the inter-lake peninsula, by Mr. Frank B. Taylor, and was done under his direction. Five weeks were occupied in making accurate measurements of the altitude of the Algonquin, Nipissing, and other shorelines at as many localities as would be needed for the reconstruction of the ancient water planes which they mark.

The value of instrumental work of this sort had already been demonstrated elsewhere in the Great Lake region, and it was believed that an application of such methods to the Ontario region would be especially fruitful, because of the peculiar relations which Ontario bears to the ancient lakes Algonquin and Nipissing. These great pro-glacial[1] lakes were known to have had temporary outlets not only down the St. Clair river (which forms the southwest boundary of the region here treated), but across southern Ontario at two places: (1) from Kirkfield eastward down the Trent valley; and (2) from North Bay eastward down the Mattawa valley. Moreover, the recent completion of instrumental surveys of these shorelines on both sides of Lake Michigan, in districts where the differential uplifts were believed to have deformed the water planes in much the same way, and to about the same extent, as in Ontario, promised to make this investigation both rapid and fruitful.

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[1] The term 'pro-glacial' means in front of the ice sheet.

The leveling was done by the writer, with the assistance of Mr. Roy C. Jacobson. Meanwhile, Mr. Taylor, and Mr. W. A. Johnston of the Geological Survey, in their field work on the glacial and lacustrine features, sought out localities where the beaches were well developed and accessible for leveling. In this way the work of making measurements was greatly expedited.

RESUME OF PREVIOUS STUDIES OF THE ALGONQUIN AND NIPISSING BEACHES.

(a) Previous Studies in Ontario.

The ancient shorelines of Ontario have been objects of interest for at least three-quarters of a century. As early as 1837, Mr. Thomas Roy—a civil engineer who had been surveying railway and canal routes across Ontario—presented a paper (which was read by Sir Charles Lyell) before the Geological Society of London, describing thirteen distinct terraces or beaches on the hillsides north of Toronto.[1] After his visit to America in 1841, Lyell wrote enthusiastically of these raised beaches, which he had examined in company with Mr. Roy.[2]

Not long after this (1853), the raised beaches and abandoned terraces around the head of Georgian bay attracted the attention of Mr. Sandford Fleming, C.E., and were described by him in a paper entitled 'The Valley of the Nottawasaga.'[3]

Ten years later Sir William Logan's report on the Geology of Canada devoted several pages to the 'ancient beaches, terraces, and ridges' of Canada. Shells were reported to have been found embedded in the lake deposits at many places, and measurements of altitude of old shorelines were recorded near Collingwood, at Meaford; at several points around Owen Sound; at Isthmus bay, and at Cabot head—on the Saugeen peninsula.[1]

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[1] 'Ancient State of the North American Continent.' Proc. Geol. Soc., London, vol. 2, 1837, No. 51, pp. 537-538.

[2] 'Travels in North America in 1841-42, with geological observations on the United States, Canada, and Nova Scotia.' London, vol. 2, 1845, p. 106.

[3] Canadian Journal. vol 1. 1853. pp. 223-226.

No systematic exploration of these raised beaches was carried on, however, until 1887. That summer and the next were spent by Dr. J. W. Spencer in surveying them, and measuring their heights. A report of this work was made by Dr. Spencer at the Cleveland meeting of the American Association, in August, 1888.[2] In this paper the name 'Algonquin beach' was proposed for the most conspicuous raised beach of the Huron-Georgian Bay region, 'Lake Algonquin' for the extinct lake, and 'Algonquin river' for its ancient outlet down the Trent valley.

Three years later, in a paper entitled 'Deformation of the Algonquin beach and birth of Lake Huron,'[3] Dr. Spencer described the course of this old shoreline along the east side of Lake Huron and the south side of Georgian bay, and presented in some detail the results of his precise measurements of altitude at twelve localities between Grand Bend and Kirkfield. The paper includes similar data for a higher beach—the 'Forest beach.'

The results of Dr. Spencer's study are especially reliable, because his measurements were made with a wye-level rather than with a hand-level or an aneroid barometer. Comparing the altitude of the Algonquin beach at his different localities, he demonstrated that the shoreline is not horizontal, but rises towards the northeast. The rate of inclination was estimated to be about 4·1 feet per mile north of Lake Simcoe, but to diminish very rapidly towards the southwest, becoming beyond Southampton only a little over 3 feet per mile. The beach was not seen south of Grand Bend. The important conclusion was drawn that subsequent to the construction of the Algonquin beach, widespread differential uplifts raised this region, giving it a southwestward slant; and that this uplift was most marked in the northern part of the region. Furthermore, from his study of certain beaches at levels below the Algonquin, Dr. Spencer discovered that the lower, later beaches are less steeply inclined than the upper, higher ones—i.e., the beaches diverge vertically towards the northeast. This was especially evident from a comparison of the Algonquin beach with the higher Forest beach. Hence, the conclusion was reached that the differential uplifts occurred during the period of formation of the shorelines instead of wholly at its close.

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[1] 'Geology of Canada.' Can. Geol. Survey, Rep't. of Progress, 1863, pp. 910-912.

[2] 'The St. Lawrence Basin and the Great Lakes' (Abstract). Proc. Am. Assoc. Adv. Sci., vol. 37, pp. 197-199, 1888.

[3] 'Deformation of the Algonquin beach and birth of Lake Huron.' Am. Jour. Sci., 4th series, vol. 41, 1891, pp. 12-21.

Previous to the writing of this paper, Dr. Spencer had worked out the probable position of the focus of those uplifts which raised the beaches of southwestern Ontario to their present altitude. This focus, he placed not far southeast of James bay.[1]

The conclusions thus logically drawn by Dr. Spencer twenty years ago have been abundantly confirmed by the present investigations, as will be seen in the pages which follow. One important exception, however, should here be mentioned. With no observations south of Grand Bend to guide him, Dr. Spencer took the average rate of descent of the Algonquin shoreline between Southampton and Grand Bend and supposed it to continue southward without further change, somewhat indefinitely. Thus he carried the plane of the shoreline beneath the present Lake Huron, and estimated that the Algonquin beach lies 20 feet under water at Sarnia. This, as it now appears, was a mistake. The conclusion was based upon measurements too far apart. In failing to follow the Algonquin beach southward to Sarnia, an opportunity was lost for establishing a fact of fundamental importance—the original altitude of Lake Algonquin above sea-level.

Previous to 1892, the extension of the Algonquin beach to the northeast and north of Georgian bay was largely a matter of conjecture. Dr. G. K. Gilbert, of the United States Geological Survey, reasoning from the facts already observed by Dr. Spencer and himself, farther south, had expressed the opinion that Lake Algonquin probably once discharged through the pass east of North Bay, Ontario, into the Mattawa and Ottawa rivers.'[2] Gilbert's theory was confirmed in September, 1892, by Prof. G. F. Wright and three companions, who visited the district between Lake Nipissing and the Mattawa, and found satisfactory indications of the former occupancy of the pass by a great river.[3]

In 1893, Mr. Frank B. Taylor made the first of several successive visits to Ontario, in which he explored the courses of the ancient outlets at North Bay and Kirkfield, and traced and measured the heights of the associated shorelines. The observations made on the first few trips were published in a series of papers, and have to do especially with the 'Nipissing outlet' at North Bay, and with the 'Nipissing beach' which is its contemporary shoreline.[1] But the papers also include descriptions of the raised beaches south of that district, around Lake Simcoe and east of Georgian bay. Most of the hand-level and aneroid measurements made by Mr. Taylor during these early visits have been either confirmed or corrected under his direction by the wye-level survey of 1908. The results of Mr. Taylor's more recent studies in Ontario are as yet unpublished; but they are to be embodied in a report on studies which he is now carrying on.

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[1] 'On the focus of regional post-glacial uplift.' Trans. Roy. Soc. Canada, vol. 7, 1889, p. 129.

[2] 'The history of the Niagara River.' New York Commissioners State Reserv. Niagara, 6th Ann. Rept., 1889, pp. 61-84; (reprinted in) Smithsonian Rept., 1890, pp. 231-257.

[3] 'The supposed post-glacial outlet of the Great Lakes through Lake Nipissing and the Mattawa River.' Bull. Geol. Soc. America, vol. 4, 1892, pp. 423-425.

A number of hand-level and aneroid measurements of raised beaches on Giants Tomb and two other islands in Georgian bay were made in 1901 by Mr. Frank M. Comstock of the Case School of Applied Science at Cleveland.[2] These measurements are of use in extending the plane of the Nipissing shoreline northward beyond the Penetanguishene peninsula, as shown in Fig. 4. None of the islands, unfortunately, rise high enough to bear a record of the Algonquin stage.

(b) Previous Studies in the United States.

Mr. Taylor's studies of the outlets and shorelines in Ontario have already been referred to. His observations even in the first year of reconnaissance (1893) extended over several hundred miles of shoreline outside Ontario. During the following years, with occasional interruptions, he carried his explorations almost completely around the Great Lakes. In the course of a few years he had worked out the general outlines of Lake Algonquin and its successor, the 'Nipissing Great Lakes,' and had found that the southwestward tilt of the water planes which Spencer had observed in Ontario extends over the whole upper Great Lake region. The Nipissing beach seemed to have been deformed in a remarkably uniform fashion, so as to mark an evenly inclined plane instead of a warped one.[1]

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[1] 'The Ancient Strait at Nipissing.' Bull. Geol. Soc. America, vol. 5, 1893, pp. 620-626.
'The Limit of post-glacial Submergence in the Highlands east of Georgian Bay.' Am. Geologist, vol. 14, 1894, pp. 252-285.
'Notes on the Quaternary Geology of the Mattawa and Ottawa Valleys.' Am. Geologist, vol. 18, 1896, pp. 108-120.

[2] 'Ancient Lake Beaches on the Islands in Georgian Bay.' Am. Geologist, vol. 33, 1904, pp. 311-318.

The measurements by which these broader features of deformation were recognized were subject to some uncertainty; for they were made partly with the hand level and partly with the aneroid. Few, if any, measurements with more precise instruments were secured. So, while a general knowledge of the Algonquin and Nipissing shorelines was extended rapidly over the whole region, certain problems were left unsolved, awaiting the use of more precise methods of study in critical districts.

Among these problems one may be selected for illustration because it was so troublesome and yet so important. What becomes of the Algonquin and the Nipissing water planes as they pass southward in the direction of their convergence? At first the same mistake was made in the Michigan basin that Dr. Spencer had made in the Huron basin: the Algonquin beach was assumed on insufficient evidence to continue its southward slant so far as to pass beneath the present lake and to be submerged 130 feet at Chicago.[2] But as more attention was directed to the raised beaches of the lower peninsula of Michigan, it became more and more evident that the southward inclination flattens rapidly before the beaches reach the level of Lakes Michigan and Huron. The hand-level and aneroid measurements failed to bring out satisfactorily the identity of these two important shorelines in the critical southern part of the region. As the Algonquin and Nipissing planes draw together, the difference in altitude between them decreasing from 180 feet at Mackinac island to 95 feet at Harbour Springs and 20 feet at Traverse City, the distinction between the beaches, at first obvious, becomes increasingly difficult and at last impossible, unless observations are made a few miles apart and a spirit level is used in place of the less accurate instruments. It is necessary that errors of measurement should be in inches rather than in feet. So, during the nineties and up to 1905, while hand-level and aneroid were still relied upon to solve the question, a state of uncertainty prevailed as to (*a*) the probable distance southward to which these differential uplifts had taken effect, (*b*) the depth of submergence of the Algonquin and the Nipissing planes below Lake Michigan and Lake Huron at Chicago and Port Huron, respectively, and (*c*) the possibility that the water planes flatten so completely southward as not to pass beneath the lakes at all.

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[1] 'The Second Lake Algonquin.' Am. Geologist, vol. 15, 1895, pp. 162-163, and fig. 6.

[2] 'Op. cit., p. 108, and fig. 3.

Observations on both sides of the lower peninsula of Michigan by Mr. Frank Leverett, and Mr. Taylor (largely unpublished), together with certain wye-level measurements by Dr. A. C. Lane and his associates on the Michigan State Survey, around Saginaw bay and the 'thumb,' were gradually changing this third idea from a possibility to a probability, when the writer, under the auspices of the Wisconsin Geological and Natural History Survey, undertook a detailed study of the raised beaches along the west side of Lake Michigan, in the critical district where the two shorelines had been thought to pass beneath the level of the modern lake.[1] This work in eastern Wisconsin differed from earlier investigations in that it covered a comparatively small field, with observations that were practically continuous along the Algonquin beach, and included measurements of altitude not only of this beach but of the complete series. The measurements were made with the wye-level at nearly fifty stations, averaging two miles apart. The study showed (*a*) that the inclination of the Algonquin beach on the west side of Lake Michigan decreases greatly towards the south, changing from about 1·6 feet per mile at Washington island to only a few inches per mile south of Sturgeon bay; and (*b*) that the few fragments of the Algonquin beach which have escaped destruction from cliff recession south of Sturgeon bay (midway down Lake Michigan) suggest a complete flattening of the Algonquin plane at a height of 25 feet above modern lake level (607 feet A.T.). In other words, the southern half of the Lake Michigan basin seemed not to have been affected by post-Algonquin differential uplifts. This conclusion was based partly on the fact that certain higher beaches older than the Algonquin seemed to be horizontal near the south end of Lake Michigan.[2]

In the summer of 1907, under the guidance of Mr. Taylor, a similar detailed survey of the Algonquin and Nipissing beaches was carried on by the writer along the east side of Lake Michigan. The results of this were stated in a brief paper in the Journal of

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[1] 'Correlation of the raised beaches on the west side of Lake Michigan.' Jour. Geology, vol. 14, 1906, pp. 411-424. 'Abandoned shorelines of eastern Wisconsin.' Bull. Wisconsin Geol. and Nat. History Survey, No. 17, 1907, 134 pp.

[3] Op. cit., fig. 3 and plate 1.

Geology.[1] Over twenty-five lines of levels were run, at stations averaging about five miles apart. In most respects the measurements here confirmed those from eastern Wisconsin. As before, however, the scarcity of remnants of the Algonquin beach made it difficult, even with precise measurements, to determine whether the Algonquin and Nipissing beaches converge to form a single horizontal shoreline at 596 feet, or whether the two beaches become horizontal at 607 and 596 feet, respectively. On the whole, the former view seemed the more probable, in spite of the fact that the latter would agree better with the conclusions drawn from the work in Wisconsin in 1905.[2]

The attitude of the Algonquin beach and its relation to the Nipissing shoreline around Lake Michigan, therefore, was still in doubt after the work of 1907, although the horizontality of both around the southern half of the lake had been thoroughly established by the recognition there of a strong shoreline uniformly 596 feet above sea-level, and of the horizontal condition of the higher beaches as far north as Holland and Milwaukee.

A summary of these detailed measurements on the east side of Lake Michigan was presented in graphic form in a map showing isobases or lines of equal deformation of the Algonquin beach over the northern half of Lake Michigan.[3]

The close correspondence between the conditions there and those which Dr. Spencer had reported from Ontario was brought out in a small map of the Great Lake region, on which a few selected isobases were extended eastward through points in Michigan to some of Dr. Spencer's points near Georgian bay and the east shore of Lake Huron.

The question of the horizontality and height of the Algonquin and Nipissing beaches around the south ends of the two lakes was one of the problems upon which it was hoped the investigations and measurements of 1908 in Ontario would throw light. That question indeed seems now to have been settled. The two shorelines seem to become horizontal at 607 feet and 596 feet, respectively, as was suggested in 1905 in Wisconsin.

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[1] 'A reconstruction of water planes of the extinct glacial lakes in the Lake Michigan basin.' Jour. Geology, vol. 16, 1908, pp. 459-476.

[2] 'Op. cit., p. 472.

[3] Op. cit., fig. 3 and plate 1.

RESULTS SECURED IN 1908.

The scope of the work in Ontario and its bearing on fundamental problems of lake history and of post-glacial deformations, is indicated in the following summary:—

(1) Measurements of altitude of the Algonquin beach (or of its supposed equivalent) have been made with the wye-level at over forty localities, distributed as follows:—

(*a*) East side of Lake Huron	7	localities.
(*b*) South and southeast shore of Georgian bay	11	"
(*c*) Lake Simcoe district	11	"
(*d*) Kirkfield-Trent Valley district	11	"
(*e*) Archæan highlands	4	"
Total number	44	"

In addition to these, a number of measurements were made at other localities with the pocket level, by Mr. Taylor and Mr. Johnston.

(2) These measurements make it possible to construct lines of equal deformation of the Algonquin beach across southwestern Ontario, Lake Simcoe, and the southern part of Georgian bay. These isobases can be extended westward across Lake Huron to connect with those previously drawn over Lake Michigan, with which they are in surprising accordance. Thus the area over which a full set of isobases of post-Algonquin deformation can be constructed has been more than doubled.

(3) The survey has fully established the connexion of the ancient outlet or 'Algonquin river' east of Kirkfield with Lake Algonquin during the stage when the 'Algonquin beach' was being constructed. And since this shoreline is also connected with the head of the St. Clair river at Sarnia, it is clearly the record of a 'two outlet' stage.

(4) The direction of tilt of this shoreline, and its rate of tilt in feet per mile have been worked out with some precision. In this respect Dr. Spencer's conclusions have been confirmed. The new observations, however, contradict Dr. Spencer's assumption that the southward slant continues at least as far as the southern end of Lake Huron.

(5) The Algonquin beach is found to become horizontal at 607 feet above sea-level, around the southern end of the lake. A line

drawn across Lake Huron not far north of Bad Axe, Michigan, and Grand Bend, Ontario, separates the northern district of differential uplift from the southern district of horizontality.

(6) The horizontality of the Algonquin beach at 607 feet around the southern end of Lake Huron gives added weight to the view that this beach in the southern part of the Lake Michigan basin is also approximately 607 feet above sea-level, as was suggested in 1905.

(7) The widespread horizontality thus approximately, if not perfectly, realized, is ground for the inference that the Algonquin beach, south of a line through Green Bay, Wisconsin, Onekama, Michigan, Bad Axe, Michigan, and Grand Bend, Ontario, stands to-day at the same height as when it was being formed. In other words, the original height of Lake Algonquin above the sea was probably 600 feet.

(8) This conclusion brings with it the means of measuring the absolute amount of uplift of other parts of the Great Lake region since Algonquin time, or conversely, of determining the height at which other parts of the Great Lake region stood, above or below sea-level, at the time when Lake Algonquin had its overflow partly down the Algonquin river and partly down the St. Clair river. By inference, also, still earlier conditions of altitude can be estimated. Now, at last, we have a datum plane from which to measure post-glacial uplifts.[1]

(9) Observations, especially by Mr. Taylor and Mr. Johnston, indicate that the tilting was much stronger close to the border of the Archæan highlands than a short distance away, amounting to 6 feet per mile. In connexion with this, the rough parallelism of the isobases with that border, across the two lakes, suggests that the uplifts originated in the substructure of the Archæan area, conforming closely to its boundaries, though started not improbably, as has been supposed, by isostatic adjustment to the removal of the heavy ice sheet.

(10) The measurements at several localities east of Kirkfield, near Balsam lake and Cameron lake, indicate that either (*a*) the Algonquin beach in that region has been warped in an unusual way,

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[1] Dr. Spencer in his paper on 'Deformation of the Algonquin beach and birth of Lake Huron' in 1890, wrote: 'We have not yet the instrumentally measurable proof that the Algonquin plane was lower than 300 feet above the sea............ for we do not know what was the initial plane of upward movement.'

or (*b*) the strong beach of that district marks a step-like series of pools between rapids on the Algonquin river. A special detailed study of this field ought to determine which is the case.

(11) Leveling at four localities between Lake Simcoe and the Mattawa valley, while correcting Mr. Taylor's aneroid measurements, does not seriously modify his conclusion that in that part of the Archæan highlands the inclination of the Algonquin beach is not uniformly southwestward, and may be locally towards the northeast.[1] The data on the Nipissing beach, however, favour the view that the highest beach at the four localities is not in every case the Algonquin.

(12) Precise measurements of altitude of the Nipissing shoreline at about twenty-five localities in Ontario, when assembled and compared with altitudes of the same beach in the United States, allow the construction of isobases for the Nipissing plane. This has not been attempted since Mr. Taylor's well-known map of 1894. The reconstruction of this plane, while confirming Mr. Taylor's original conclusions in the main, differs from it in certain important particulars—e.g., the plane becomes horizontal southward (at an altitude of 596 feet), instead of slanting beneath the lake. The post-Nipissing uplifts are found to have acted from a slightly more easterly direction than the earlier uplifts, but to have affected virtually the same portion of the Great Lake region.

The foregoing conclusions will be reviewed at the end of the paper, after the evidence supporting them has been presented.

SHORELINES OF LAKE ALGONQUIN AND ITS SUCCESSORS IN ONTARIO.

The newly collected data concerning altitudes of the Algonquin, Nipissing, and other shorelines may, for convenience, be divided into five parts, representing five rather distinct geographic districts: (*a*) the east shore of Lake Huron; (*b*) the south and southeast shores of Georgian bay; (*c*) the Lake Simcoe district; (*d*) the Kirkfield-Trent Valley district; and (*e*) the Archæan highlands. For each district the measurements will first be given in tabular form; following this will be a short discussion of the conditions in each. All localities are shown on the large map, Fig. 1.

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[1] This conclusion was reached in 1896 (*see* 'Notes on the Quaternary Geology of the Mattawa and Ottawa valleys.' Am. Geologist, vol. 18, pp. 118-119), but the possibility that the highest beach at some of these localities might not be the Algonquin beach was recognized.

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(a) The East Shore of Lake Huron.

Wye-level measurements from the lake up to the highest Algonquin beach resulted as follows:—

Locality.	Altitude of the Algonquin shoreline.	Description of beach or terrace, and of place where measured.	Altitude of the Nipissing shoreline.	Description of beach or terrace, and of place where measured.	Other shorelines.
	Feet.		Feet.		
Sarnia	606-607	Beach ridge. On main road 1 mile east of town.	596	Gravelly beach, with sandy crest, 700 yards back from lake near Port Edward.	Several other ridges, above and below the Nipissing, but none so continuous. Upper ones gravelly, lower ones sandy.
Kettle Point..	607	Base of cut bluff, 2 miles back from shore, on east-west road, 3 miles south of Kettle Pt.			
	606	Sandy ridge close to last.	596	Sandy ridge, 100 yds. out from last.	Sandy ridges between these, at 600, 602, and 603 feet.
Grand Bend..	607	Gravelly beach ridge recently exposed by migration of dunes, at shore 1½ miles north of village, and a quarter of a mile north of Maple Grove.	....	....	Modern dunes cut back by waves to low cliff, leave no chance for beaches at lower levels than Algonquin.
Bayfield	613	Terrace at base of 15 ft. bluff at shore at J. Watson's, (formerly Wilson's) 4 miles south of village.	....	....	Modern cliff rises to 610 feet.

Locality.	Altitude of the Algonquin shoreline.	Description of beach or terrace, and of place where measured.	Altitude of the Algonquin shoreline.	Description of beach or terrace, and of place where measured.	Other shorelines.
	Feet.		Feet.		
Kincardine...	665	Barrier beach, 1 mile south of centre of town, at north edge of cemetery. Was built half a mile off shore with a shallow lagoon behind.	600	Base of bluff near lake, due west of last.	Obscure beaches noted at 641 feet, railway crossing, and 657 feet in cemetery.
	667	Same barrier, on Albert st., ½ mile north of cemetery.	604	Base of bluff at foot of Albert street.	Beaches at 636 feet (?), 646 feet (good), 651 feet (?), and 660 feet (good).
Baie du Doré.			618	Bench at foot of a low but sharply cut bluff.	Remarkably high steep bluff with base at 661 feet, half a mile back from shore. Too low to correspond with the Algonquin. Lower beaches at 610 and 612 feet.
Port Elgin ...	710	Barrier beach connecting with high kame on Saugeen road. On east-west road 1½ miles south of village.	614	Base of 20 ft. bluff behind dunes near shore, at elbow of road, west of last.	Beaches at 671 feet (?) 689, 696, and 702 feet.
Southampton.			618	Beach of fine gravel, in lot back of Catholic church.	Beaches, mostly sandy, between Nipissing and lake, at 597, 601, 603, 605, 608, 607 and 611 feet (at Mr. Bowman's house).

This east shore of Lake Huron does not afford many localities for observations; for the modern cliffs have very generally been cut back past the old shorelines into higher ground. The stretch of forty-four miles between Kincardine and Bayfield with no measurements is due to this lack of preservation of the Algonquin beach, and to the difficulty of discovering, in the few days assigned to this district, such fragments of it as the one which still remains at Bayfield. At Goderich the modern cliffs are 50 to 100 feet high, except close to the mouth of the river, where they have been cut back across a well-defined river terrace whose altitude is 607 feet. This is about 20 feet too low to be a flood plain adjusted to the Algonquin stage. It probably belongs to the Nipissing stage of the lake, since the Nipissing shoreline, if it were here, should occur at an altitude of about 600 feet, and this flood plain fragment is an unknown distance up-valley from the shore of Nipissing time. Eighteenmile creek, one of Dr. Spencer's localities for the Algonquin beach, proved to be a disappointment. A number of river terraces were found at the mouth of the creek; but not a sign of a shore terrace. The modern cliffs have been cut back into higher ground. Possibly a shore terrace, once measured by Dr. Spencer, has been consumed by the cliff recession of the last twenty years.

In spite of this destruction of the record, the six good localities where the Algonquin beach is strongly developed (Sarnia, Kettle Point, Grand Bend, Bayfield, Kincardine, and Port Elgin) suffice to show its attitude. From Sarnia northward to Grand Bend at least the beach is virtually horizontal at 607 feet. A few feet must be allowed, of course, for the constructional variation and for small errors of leveling. This horizontality of the Algonquin beach at 607 feet agrees with observations on the west side of the lake, in Michigan, and with the writer's conclusions in eastern Wisconsin. There is no mistaking the Algonquin beach; it is stronger than any other except the Nipissing.

North of Grand Bend (and an unknown distance south of Bayfield) the Algonquin beach begins to rise towards the northeast. The exact direction of ascent cannot be determined from the few observations in the table, alone; it is based on more complete data farther north, as will be explained later. The distance between Bayfield and Kincardine, measured in the direction of tilt (N 21° E) is forty-four miles; the difference in altitude of the Algonquin beach at the two places is (666–613 feet) 53 feet, making the average tilt for the first fifty miles or so, 1·43 feet per mile. The distance from Kincardine to

Port Elgin is twenty-one miles; the rise in the Algonquin beach is (710–666 feet) 44 feet; so that the tilt rate here is 2·10 feet per mile. All this is shown graphically on the profile, Fig. 2.

Turning now to the Nipissing beach, we find imperfect evidence of its horizontality south of Grand Bend in the agreement of certain beach ridges at Sarnia and Kettle Point, both 596 feet. It was not thought necessary to take time to discover more localities for this beach in this district, because the horizontality of the older, higher Algonquin beach seemed certain, and data were available along the Michigan shore, and especially around the head of Saginaw bay, to show the Nipissing beach to be essentially horizontal at 596 feet. In the twenty-one miles from Kincardine to Port Elgin the Nipissing beach rises (614–600 feet) 14 feet—i.e., its tilt rate here is only 0·67 feet per mile. There is no measureable change in rate between Port Elgin and Southampton. These facts, also, are brought out in Fig. 2.

(b) South and Southeast Shores of Georgian Bay.

In this table the order of localities is geographical, following the shore from near the end of the Saugeen peninsula southward and eastward to the Penetanguishene peninsula and Machedash bay. In all but five cases (Park Head Junction, Colwell, Elmvale, Wyebridge, and Coldwater) leveling proceeded from Georgian bay as a base. At the first three the railway station was the base; at the last two, slack water in creeks tributary to the bay was accepted as approximately bay level.

Locality.	Altitude of the Algonquin shoreline.	Description of beach or terrace, and of place where measured.	Altitude of the Nipissing shoreline.	Description of beach or terrace, and of place where measured.	Other shorelines.
	Feet.		Feet.		
Dyers Bay...	......	Highest point reached was 691 feet, too low for record of the Algonquin.	641	Chipstone beach at top of hill on road, above Willis Kent's lumber camp.	Benches at 593, 609, 610, 618, 623 feet. Beaches at 634, 684, (?) and 686 feet (?).

Locality.	Altitude of the Algonquin shoreline.	Description of beach or terrace and of place where measured.	Altitude of the Nipissing shoreline.	Description of beach or terrace and of place where measured.	Other shorelines.
	Feet.		Feet.		
Lions Head..	......	No ground above 750 feet. Algonquin estimated to be 820 feet.	636	Beach at base of low bluff, southeast of village, on road to headland.	Magnificent series of chipstone beaches at head of bay, in pastures and lots in southeast part of town. Twenty of them between Nipissing and shore, at intervals of a few feet.
			642	Strong barrier, continuation of last. Runs under church, south of town.	At 665 feet, strong, broad, gravelly ridge crosses Saugeen road just south of town. At 673 feet, another, a quarter mile south of last. Obscure gravelly ridges on hills southeast of town, 692, 697, and 723 feet.
Hope Bay....	......	Highest ground falls far short of Algonquin level.	636	Conspicuous deepwater barrier on road to shore at head of bay.	621 feet, strong beach in front of Nipissing. 629 feet, crest close behind Nipissing. 664 feet, distinct beach near foot of cliffs on hill. No more shorelines up to 724 feet.
Wiarton.....	774 to 779	Cobblestone beach encircling crest of hill above reservoir. No chance for higher record on this hill.	(626)	Sloping bench at foot of 40 ft. cliff, in northwest part of town, near hotel.	Between shore and reservoir, no beaches except Nipissing until 743 feet strong cobblestone ridge at Mr. Dobson's house; 745, 750, 763, 770 feet, and finally the highest Algonquin.
			630 and 635	Gravelly beaches in south part of town near railway.	Above the Nipissing are two others;— 649 feet, weak beach; 656 feet, heavy one.
Park Head Junction....	738	Indistinct bluff in field about 500 yards east of station.	.....		

Locality.	Altitude of the Algonquin Shoreline.	Description of beach or terrace, and of place where measured.	Altitude of the Nipissing shoreline.	Description of beach or terrace, and of place where measured.	Other shorelines.
	Feet.		Feet.		
Owen Sound.	748	Great gravel spit on Union St. near Brown St. In some places a lower crest, also, at 747 feet.	633	Base of high bluff near school on Union St.	
			627	Fine gravelly bar on shore road; one mile northwest of town.	Low gravelly beach at 592 feet.
			625	Base of distinct 15 ft. bluff in field 4 miles northeast of town.	Flattish ridge of gravel on road near shore at 603 feet.
Hogg P.O....	778	Strong chipstone ridge at house used as post-office.	625	Base of bluff near shore. Rather irregular.	No distinct shorelines above Nipissing until 745, 748, 761, 771 feet beaches, and finally highest Algonquin.
Presqu'ile....	....	....	625	Base of steep, sharp bluff, 300 yards back of post-office.	Fine series of bayhead beaches between shore and Nipissing bluff, at 593, 595, 598, 606, 612, 622, 625 feet.
Meaford......	783	Distinct gravelly beach on road at concession xxi, 2 miles west of shore.	629	Base of conspicuous bluff with heavy boulder pavement, near shore east of last.	Below the Nipissing, rather indistinct beaches at 607 and 612 feet. Just below the Algonquin, distinct beaches at 773 and 777 feet.
Clarksburg and Thornbury.	770	Indistinct bluff cut in till, on road, 1 mile due west of Clarksburg.	632	Base of bluff in village of Thornbury.	In Thornbury from shore near station southwestward through village, are gravelly beaches at 593, 601, 602, 612, and 620 feet. Beyond Nipissing bluff at 657 feet, a ridge of fine gravel. West of Clarksburg, near the Algonquin beach, are beaches at 737, 743, 746 and 750 feet.
	769	Coarse gravelly beach just in front of last.			

Locality.	Altitude of the Algonquin shoreline.	Description of beach or terrace, and of place where measured.	Altitude of the Nipissing shoreline.	Description of beach or terrace, and of place where measured.	Other shorelines.
	Feet.		Feet.		
Mair Mills...	767	Gravelly beach 50 feet out from base of bluff, a mile south of Mair Mills and ¼ mile along east-west road.	632	Base of steep 15 ft. bluff, on road north of last, half-way to shore.	
Colwell	774	Great gravel bar ¾ mile northwest of station, on road to Vespra.	.....	....	A sandy spit with crests at 755 and 752 feet crosses road just southeast of Colwell Station. Is an extension of the 774 ft. bar, built at a later, lower stage.
Elmvale......	829	Base of high bluff in pasture 4 miles northeast of town.	......	....	804 ft. Cobblestone-beach in same pasture.
Wyebridge. ..	840	Base of distinct bluff in woods, ⅜ mile east and ¼ mile south of village.	637	Sharply defined terrace, 200 feet broad, with steep bluff, on side hill below road.	Less distinct terraces on same hillside, at 618 and 658 feet.
Penetanguishene	855	Gravelly spit at road corner 4 miles northwest of town.	635	Terrace at foot of irregular gullied bluff, on road from head of bay northwestward.	Other terraces on same slope at 658 and 698 feet, former most distinct of all.
			639	Strong terrace and 25 ft. bluff ¾ mile north of town, on steep hillside.	Strong bluff and terrace at 665 feet (graded for street). Rather distinct terrace at 705 feet. At 785 feet, low but distinct sandy ridge around rim of outwash plain. This plain varies from 785 to 793 feet.
Coldwater.. ..	852	Base of 30 ft. bluff, in sheep pasture on hill a mile west of village.	635	Obscure bench in bouldery pasture ¾ mile west of village.	On same hillside are: sandy beach at 611 feet, just above road; 672 feet, sandy beach in same pasture; 706 feet, broad beach above last.

As the table indicates, the absence of the Algonquin beach from the first three localities on the list is due to the fact that no ground was found on the Saugeen peninsula high enough to register the plane of this highest beach. At this stage of the lake the entire peninsula north of Wiarton appears to have been submerged. The record of the lower shorelines, however, especially the Nipissing, is very strong.

From Port Elgin to Wiarton the distance (in the direction of tilt) is twenty-seven miles. In this distance the Algonquin beach rises (776–710 feet) 66 feet, or at a rate of 2·44 feet per mile. In the same stretch the Nipissing shoreline rises (633–614 feet) 19 feet, or at a rate of 0·70 feet per mile. Comparing these two rates with those of the same two shorelines south of Port Elgin (given on p. 21), one finds that each rate has increased northward, the Algonquin (from 2·10 to 2·44 feet per mile) much more distinctly than the Nipissing (from 0·67 to 0·70 feet per mile). These changes in slant appear plainly on the profile Fig. 2.

It will be noticed that the altitude of the Algonquin beach at Clarksburg, Mair Mills, and Colwell varies only slightly from 770 feet, and that the measurements at Wiarton, Hogg P.O., and Meaford are close to 780 feet. Since these stations of accordant altitude are far apart, in each case, they enable us to construct two lines of equal deformation of the Algonquin beach along the south coast of Georgian bay, and to work out the exact direction of steepest inclination there. These six stations are of similar value in locating lines of equal deformation of the lower, Nipissing shoreline.

The data gathered from Penetanguishene and Coldwater are of especial interest, because these places are farther north than the others, and within ten or fifteen miles of the border of the Archæan highlands. As Fig. 2 shows, these measurements indicate that the Algonquin plane rises from Owen Sound as far north as the Penetanguishene peninsula without any measureable increase in slant—a fact which is important in fixing the limits of a distinct steepening of the plane just north of here.

(c) Lake Simcoe District.

The measurements around Lake Simcoe are necessarily limited to the Algonquin beach and those close to it in altitude. Lake Simcoe itself is 718 feet above sea-level—far above the plane of the Nipissing shoreline. The district is peculiarly well adapted for making measurements of the Algonquin beach, not only because that beach is well marked, but because it stands near the lake, and only from 30 to 150 feet above it. The measurements which follow were all made with the wye-level from Lake Simcoe as a base, unless otherwise stated. Eight of them, as the list indicates, were made by Mr. Taylor and Mr. Johnston with the pocket level[1] after the writer had left the field.

Locality.	Altitude of Algonquin.	Description of beach or terrace and of place where measured.	Other shorelines.
	Feet.		
Schomberg..........	724	Terrace and bluff on road ¾ mile south of Dunkerron (Taylor and Johnston)	
Beeton.............	729	Terrace and bluff near Grand Trunk ry., ¾ mile north of station. (Taylor and Johnston.	
Bradford...........	749	Terrace and bluff near station. (Taylor and Johnston).	
Holland Landing....	752	Ridge near base of bluff, a mile north of station.	
Lefroy.............	775	Beach ridge, on west side of railway, near station. (Taylor and Johnston).	
Big Bay Point......	795	Beach ridge, 2 miles west of point, near Kempenfeldt bay. (Taylor and Johnston).	
Allendale	782	Base of cut bluff in southeast part of town.	
Barrie.............	785	Base of cut bluff in yard on Collins St.	
Gowan	795	Base of cut bluff back of Shanty Bay settlement.	

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[1] This instrument, known as the 'German pocket level,' is for sale by Eugene Dietzgen Co., Chicago. It is well adapted to work like that which is here described, for it is very light and convenient to carry, yet capable of yielding precise measurements when used with a rod and rodman.

Locality.	Altitude of Algonquin.	Description of beach or terrace and of place where measured.	Other shorelines.
	Feet.		
	796	Same, ⅜ mile east of last.	
	798	Same, ⅜ mile east of last.	
	800	Same, near railway crossing, 1½ miles east of Gowan.	
Oro	811	Base of cut bluff a short distance west of station.	
Hawkstone	821	Base of 25 ft. cut bluff just west of station.	
Orillia	847	Base of cut bluff ¼ mile north of centre of town.	
	850	Great barrier beach 1½ miles northwest of town (Johnston).	
Silver Creek	869	Cut terrace and bluff, a mile northeast of station, on road to Hampshire Mills. (Taylor and Johnston).	
Ardtrea	883	Beach ridge, 1½ miles north of village on road. (Taylor and Johnston).	
Beaverton	822	Strong gravelly beach in field east of road and 1½ miles south of town.	In village: 785 feet, beach near brick church; 797 feet, beach 300 yards farther south; 802 feet, distinct beach in field east of road; 812 feet, base of strong 15 ft. bluff in same field; 812 feet, limestone cliff and terrace close to road farther south, ¾ mile south of village; and in same field with the Algonquin, beach ridges at 810, 812, 817, and 818 feet.
Lorneville Junction	[(838)	Heavy gravel ridge, thought to be a great barrier beach; but may be a deposit of other than littoral origin. Cut by railway, 2½ miles west of station. (Railway sta. base, 892 feet).	Several lower ridges sandy and flattish on swampy ground farther west, along railway.

The Algonquin beach has been measured in greater detail between Allendale and Orillia than in any other district. The shoreline can be followed with nearly perfect continuity all the way, a distance of about twenty-five miles. The leveling itself was continuous along the Algonquin beach from Gowan for two miles towards Oro; and as the four measurements (795 feet, 796 feet, 798 feet, and 800 feet) show, the Algonquin terrace at each locality proved to be a little higher than it had been at the last point, only three-eighths of a mile away. In other words, the rate of ascent (even in a direction somewhat oblique to the direction of steepest ascent) was strong enough to overshadow initial irregularities in construction of the terrace. For economy of time, it was thought best not to run levels continuously from Barrie to Orillia, but to choose stations at intervals of a few miles; the result is a chain of nine stations between Allandale and Orillia, averaging 2·20 miles apart in the direction of tilt (N. 21° E). The tilt rate which these measurements indicate for the central part of the Lake Simcoe district is 3·25 feet per mile.

North of Orillia, on the west side of Lake Couchiching, the three measurements made by Taylor and Johnston (850 feet, 869 feet, and 883 feet) indicate a rapid steepening of the inclination of the Algonquin beach. In the six miles between the station at Orillia (847 feet) and Ardtrea (883 feet) the tilt rate averages 6 feet per mile. This is close to the border of the Archæan highlands. In the next section attention will be called to a corresponding increase of tilt of the water plane near the Archæan border in another district, that around Kirkfield and Balsam lake.

It was hoped at first that this survey of the Algonquin beach in the Simcoe district would succeed in carrying the water plane southward until it actually reached the level of Lake Simcoe, disappearing beneath it somewhere near Cook bay. Thus might an ancient beach be really observed to pass under water,[1] after the manner once assumed for the Algonquin plane near the southern part of Lake Huron and the middle of Lake Michigan (*see* pp. 10 and 12). But as

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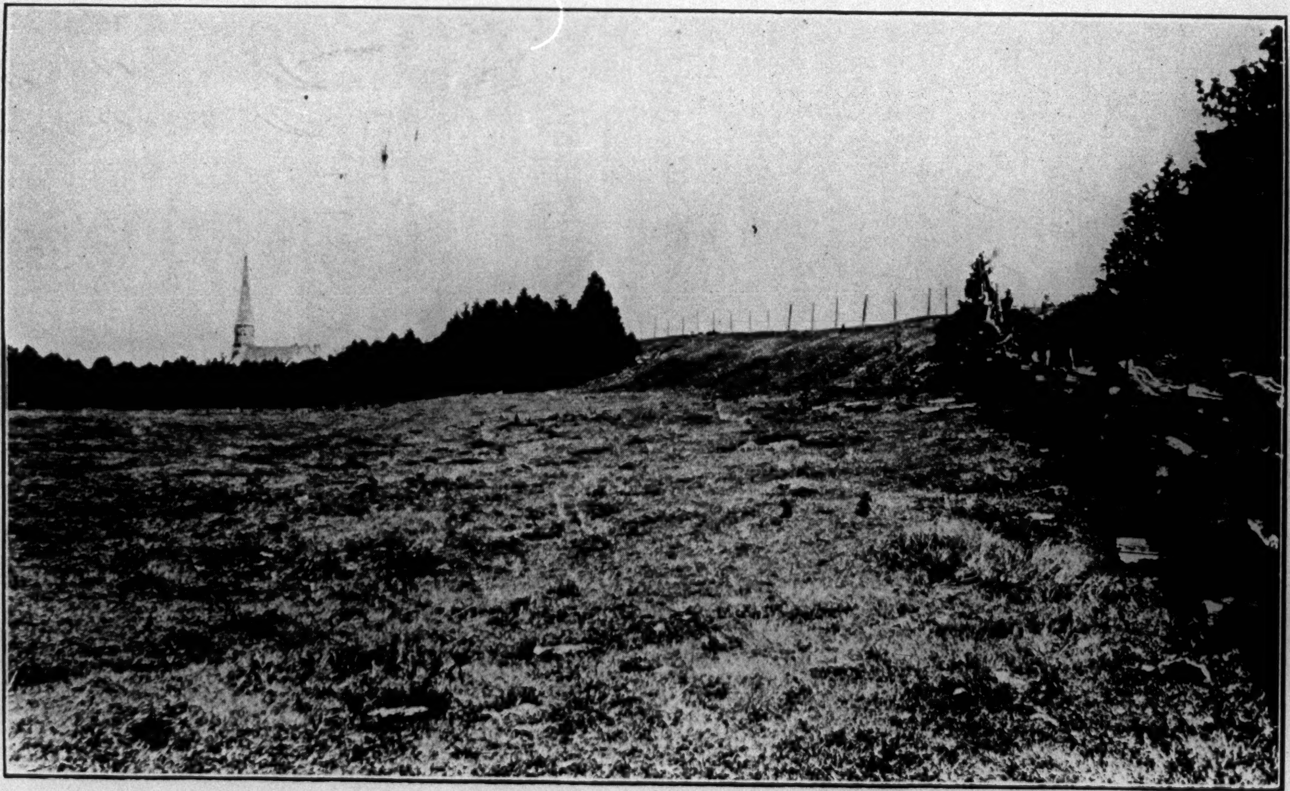
[1] The Nipissing shoreline is thought to pass beneath Lake Superior east of Duluth (see paper by F. B. Taylor, 'The Nipissing beach on the north Superior shore.' Am. Geologist, vol. 15, 1895, pp. 307 and 312). The marine 'Oswego' beach of the Ontario basin is believed to dip beneath Lake Ontario with westward inclination; as indicated chiefly by the investigations of Dr. G. K. Gilbert and Dr. A. P. Coleman. (*See* paper by H. L. Fairchild, 'Gilbert Gulf [Marine waters in the Ontario basin].' Bull. Geol. Soc. America, vol. 17, 1905, pp. 712-718).

PLATE II.



Algonquin bluff at Beaverton, 812 feet.

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the work progressed it was found that the southward inclination is insufficient to produce this phenomenon. In fact, the tilt rate decreases markedly towards Allandale, averaging 2·30 feet per mile between Allandale and Schomberg, so that the Algonquin plane passes over the extreme head of Cook bay at an altitude of about 765 feet, or nearly 50 feet above the level of Lake Simcoe. The wye-level measurement at Holland Landing sufficiently shows this, but is supplemented by three or four observations by Taylor and Johnston in the above table. It will be seen that near Schomberg at the southernmost point to which the Algonquin shoreline was traced by Mr. Taylor in the Simcoe basin, the beach has an altitude of 724 feet, only 6 feet above the level of Lake Simcoe. The most important fact thus established is that Lake Algonquin had no overflow across the height of land between Lake Simcoe and Toronto. This height of land is over 900 feet above sea-level, fully 200 feet too high for Lake Algonquin to have discharged southward across it.

(d) Kirkfield-Trent Valley District.

Four days were occupied with leveling in the district east of Lake Simcoe, around Balsover, Kirkfield, and Balsam lake. This is in some respects the most interesting district studied. It includes the head and upper portion of the ancient outlet, the 'Algonquin river' of Dr. Spencer. It lies close to the Archæan border, showing as a consequence the excessive tilt mentioned on page 28; so an effort was made to obtain as many measurements on the Algonquin plane as time would permit. The results, while not as complete as might have been secured in a longer time, are significant. Since these measurements from the Kirkfield district do not lend themselves to arrangement in tabular form, they will be listed in geographical order. The altitudes were determined by wye-level from the Trent canal, and from natural and artificial lakes along its course.

(*a*) Balsover[1].

Algonquin beach at gravel pit on Portage road, just east of Balsover, a fine gravel bar, 857 feet. Lower beaches just west of Balsover village, at 800 feet, 802 feet, 806 feet, 815 feet.

Algonquin beach 100 yards east of Portage road, half a mile north of last, 861 feet. Algonquin beach on Portage road, at turn three-quarters of a mile north of last, 865 feet. Another beach on the west side of Portage road, below last, and a little farther south, 853 feet.

A beach of slabs and chipstone on the road just west of the north end of drowned land a mile east of Cranberry lake, 852 feet. The ground here does not rise much higher.

(b) Kirkfield and Victoria Road.

Algonquin beach on road to lift lock half a mile north of Kirkfield station, a gravelly beach ridge with three parallel crests; highest crest, 883 feet; middle crest, 880 feet; lowest crest, 880 feet. Obscure beach close below last, 872 feet.

A mile and a half north of the lift lock; chipstone beach, 883 feet, with a lower crest at 881 feet on its north side.

Two miles north of lift lock: double-crested coarse chipstone beach, 888 feet.

Not only the 883 ft. beach south of the canal, but the 883 and 888 ft. beaches a mile or two north of it appear to have been built by waves from the north. The imbricated chipstone structure shows this. It seems probable, therefore, that the greater height of the 888 ft. beach north of the canal is due to differential uplifts which raised an originally lower Algonquin beach to an altitude 5 feet higher than the true Algonquin beach a few miles farther south. The strong 883 ft. beach ridge north of Kirkfield station, therefore, may be regarded as the Algonquin beach itself, cast up along the southern edge of the shallow bay which led to the Algonquin river.

Northeast of Kirkfield station this Algonquin beach curves so that it crosses the railway not far west of the canal. Its altitude here is only about 873 feet. A few hundred yards north of the railway and close to the bank of the canal the beach is intersected by a fault which appears in cross-section in the limestone walls of the canal. The humpy surface of the beach here, varying from 875 to 878 feet, may be the effect of a slight post-glacial movement or earthquake tremor along this fault.

The fault has been traced by Mr. Johnston for more than half a mile northwest from here to the vicinity of the lift lock, where it crosses the road at a corner a quarter of a mile south of the lock. Along the fault line is a slightly up-arched ridge of limestone, covered with broken slabs of the rock. That the post-Algonquin uplifts were attended by a slight local dislocation or buckling of the limestone along this plane seems probable, or at least, possible. Again, it is perhaps significant that the Archæan boundary is only a few miles north of here, and the limestone has a slight thickness.

In the shallow, irregular basin between Kirkfield and Victoria Road, a distinct shoreline was measured at four localities. At each place no higher stage has been registered, although topographic conditions would have permitted it.

At little gravel pit on road, a mile south of Victoria Road, 878 feet. Three-quarters of a mile farther south on same road, and a quarter of a mile north of the channel, a bluff and terrace at 868 feet. On island-like hill just east of the high bridge beach on south side, at east end of hill, 875 feet; beach at north side, at west end, 871 feet.

A careful comparison of the measurements east of Kirkfield with those at and west of Kirkfield, such as is indicated by Fig. 1, shows a distinct discordance between the two sets. The four just mentioned seem all to be lower by about 15 feet than they should be if the Algonquin isobases extend past Kirkfield without an abrupt change of direction. The same is true of measurements around Balsam lake, as will presently appear. Two explanations suggested themselves when this was discovered, and before all the measurements had been made. (*a*) The post-Algonquin deformations just east of Kirkfield were irregular, involving warpings or faultings of sufficient magnitude to bring these four points 15 feet 'too low.' Crooked isobases, then, would have to be drawn for 870 feet and 880 feet. In favour of this view is the existence of at least one fault in the neighbourhood, where recent dislocation seems to have occurred; also the marked steepening of tilt near the border of the Archæan area might be attended by irregularities similarly local and marked. A valid objection to this view, however, consists in the regularity of tilt over the wide area as shown by isobases plotted from measurements already given (Figs. 1 and 3). No such discordance as 15 feet has been discovered elsewhere in the Great Lake region, where precise measurements have been secured. In the face of such remarkable regularity of inclination, not only in Ontario, but over the two sides of Lake Michigan, one does not feel like recognizing a local irregularity without more positive evidence. (*b*) An alternative is found in the idea that these four measurements are lower, because they are part way down the valley of the ancient Algonquin river. It is quite possible that the ancient outlet began its descent at Kirkfield, and that even as near its head as this the river surface had declined several feet in level. There is a smoothly-swept rock surface just east of Kirkfield near the high bridge which, if it represents the scoured floor of Algonquin river, indicates a strong current and a decided fall in water level down the outlet. This explanation, when first suggested by the measurements, was not entertained without reluctance; for Mr. Taylor's former studies had favoured the view that the controlling point of the old outlet was twelve miles east of here, at Fenelon Falls. Moreover, the valley near Kirkfield seems almost too wide to have allowed the deep Algonquin river to fall perceptibly in so short a distance. What further date were secured, however, in the season of 1908, lend weight to the view that there was a down-stream inclination even at Kirkfield.

The choice between these two explanations can, of course, be settled only by a detailed study of the district. If the phenomenon is due to local warping and faulting, the beach measurements should bear a confused, discordant relation to one another; if it is a sign of original slope down the outlet, the beaches might be expected to show a systematic discordance—for this reason. The Trent River system of to-day is a chain of lakes, the four uppermost being Balsam lake, Cameron lake, Sturgeon lake, and Pigeon lake. These basins of to-day with their connecting rapids must have been basins formerly on the course of the Algonquin river; and each basin ought to have its extinct shoreline, a shoreline that was constructed when the Algonquin beach was being formed farther up, at the head of the outlet, in the open lake.

Fortunately, although these lakes are comparatively small, they are large enough to have possessed recognizable beaches—at least at the highest stage, when the Algonquin river was active. Measurements were secured on this beach at four places on Balsam lake and one on Cameron lake, as follows:—

West side of Balsam lake, at Laidlaw's estate; base of distinct bluff 100 yards north of place where canal enters lake, 867 feet.

At school-house, an eighth of a mile west of last, a bench apparently continuous with it, 866 feet.

East side of Balsam lake, on road to Baddow, a quarter of a mile east of the lake, distinct beach in field west of school-house on south side of road, 895 feet. Below it are other beaches at 891 feet, 886 feet, 884 feet.

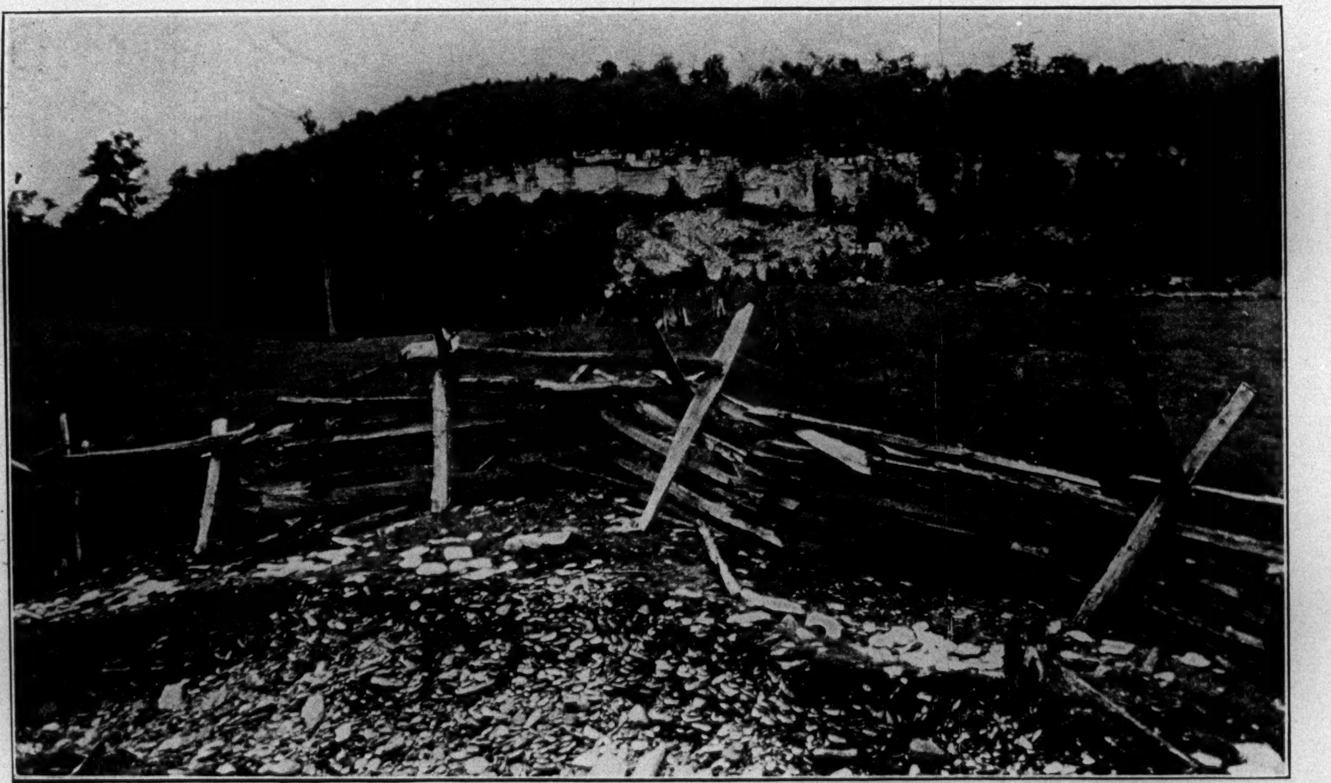
At Rosedale, a half mile south of the lock, close to the lake, on the road, a stony beach, 884 feet.

At south end of Balsam lake, near elbow of road at shore on east side of cove, very faint ridge, low cut, and obscure fan, 868 feet.

On the south side of Cameron lake, a mile west of Fenelon Falls, a set of gravelly beaches between granite knobs in a field between the road and the lake shore, small but wonderfully delicate and perfect. Highest, 867 feet, others at 863 feet, 859 feet, and 855 feet. Also a sharp 10 ft. bluff with base at 839 feet.

These points show a discordance like those in the district just east of Kirkfield, viz., they are much too low to fit the extended water plane of Lake Algonquin. Either that plane has been much and irregularly deformed, in this district, or the beaches are not the beaches of the lake itself but of a chain of pools on the Algonquin river. The points at which measurements were secured are too few to indicate which is the correct explanation; but the distinctness of the beaches at places on these small lakes offers hope that a detailed study of the district will settle the problem. It is a unique state of things, however interpreted, and deserves special investigation.

PLATE III.



Nipissing barrier at Hope bay, 636 feet.

(e) Archæan Highlands.

Previous to 1908 the raised beaches in the long stretch east of Georgian bay and Lake Nipissing had been measured only by the aneroid barometer and the hand-level.[1] Three days were, therefore, devoted to the levelling of the shorelines at four of Mr. Taylor's localities: Bracebridge, Huntsville, Trout Creek, and North Bay. The corrections that resulted, in the first three cases, were trivial, amounting to only a few feet. The highest beaches at North Bay ('Nelson' and 'McEwen' beaches) were found to be nearly 40 feet higher than they had formerly been determined to be. The chief value, however, of this short visit to the highlands was in the fixing of the Nipissing beach at an altitude of 697 feet at the head of the ancient Nipissing outlet at North Bay. This is the only point in the Archæan highlands east of Georgian bay where the Nipissing shoreline has been measured with accurate instruments. It is the only guide to the drawing of isobases on the Nipissing plane in this northern country.

The measurements follow:—

(*a*) Bracebridge.

Levels run from the railway station as a base (812 feet A. T.) eastward and northward two miles by road to house of Philip Leeder. Steep sharp bluff and bench at Leeder's supposed to be the Algonquin because of its strength, 989 feet. On the brink of this bluff a low ridge, perhaps a beach, 1007 feet. An eighth of a mile east of Leeder's in cemetery, a light but distinct beach, 1001 feet. Coarse gravel beach on ancient island at gravel pit, three-quarters of a mile west of Leeder's, 986 feet. This is evidently a continuation of the supposed Algonquin shoreline. Strong broad bar that tied the ancient rocky island to the high ground near Leeder's, 968 feet. Other beaches in same field near ancient island, 962 feet (faint), 957 feet, 952 feet, 947 feet (faint).

(*b*) Huntsville.

Levels run from railway station (951 feet A. T.) as base. Base of steep bluff opposite Vernon hotel, 1007 feet. This is strong, so seems likely to be the Algonquin.

(*c*) Trout Creek.

From railway station as base (1034 feet A. T.). At Weiler's farm, three miles north of town, crest of gravelly beach at foot of round kame, 1221 feet. Lower ridge of gravel 100 yards south of last 1215 feet. On the road east of the station, in the woods, a broad flat was found at 1199-1209 feet, which might be a shoreline; but it lacks character. Terraces that looked promising were seen on a cleared hill southeast of the station, but there was not time to run levels up to them.

(*d*) North Bay.

Levels run from the station as base (658 feet A. T.) to Nelson's farm, five miles northeast, on the Timiskaming road. Gravelly beach at Nelson's, three crests, 1178 feet and 1176 feet. This is the highest beach found by Mr. Taylor at North Bay. Gravelly beach at Sache's (formerly McEwen's), 1129 feet. Less than a mile north of town, near corner where Timiskaming road turns eastward beyond old water tower, a strong beach at the road corner, 777 feet. This was found and measured again three-quarters of a mile east of the corner, at a cemetery, 779 feet. Another good beach in the pasture an eighth of a mile east of the old water tower, not far south of the road, 764 feet. Very strong beach in same pasture as last, 300 yards south of the road, 748 feet. Base of strong Nipissing bluff where crossed by Timiskaming road near old water tower, 697 feet. Spit of gravel east of last, and formed of material swept along shore from it, 698 feet.

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[1] F. B. Taylor, 'Post-glacial submergence in the highlands east of Georgian Bay.' Am. Geologist, vol. 14, 1894, p. 285; and 'The ancient strait at Nipissing.' Bull. Geol. Soc. America, vol. 5, 1893, p. 620.

The opportunity for tracing the outline of Lake Algonquin through the highlands east of Georgian bay is very poor. The upland was so rough, and the outline of the lake was consequently so ragged that full exposure to wave action was the exception rather than the rule. Even where the exposure was severe the crystalline rocks furnished less favourable material for beach construction, and resisted cliff cutting more than the Palæozoic limestones and shales of the region farther south. It is natural, then, that well shaped beaches are rare. A large part of the region is still forested; roads are scarce, especially on the highest ground; and exploration of the old shorelines must necessarily be very slow and incomplete. There is still another difficulty in placing the Algonquin beach north of the Trent outlet. That is, the strong Algonquin beach which records the combined activities of the Trent and Port Huron outlets probably splits vertically into several diverging shorelines, at a point near ments. It is necessary that errors of measurement should be in the level of the pass at Port Huron.[1]

The incomplete data thus far collected from this difficult field give little ground for the proper correlation of the Algonquin shoreline. If the comparatively strong benches and beaches at Bracebridge, Huntsville, Trout Creek, and North Bay are the Algonquin, as was once supposed, they indicate that the Algonquin plane does not continue to ascend so far northeastward at the same rate as near Orillia nor at an increased rate, but that it is irregularly warped or faulted. If this proves to be the case it adds another very serious obstacle to the complete investigation of the raised beaches in the Archæan area.

The rates of ascent of the Algonquin shoreline, assuming that the 'highest beach,' originally supposed to be the Algonquin at the four localities is indeed that one, and that the direction of tilt is N 22° E, would be as follows:—

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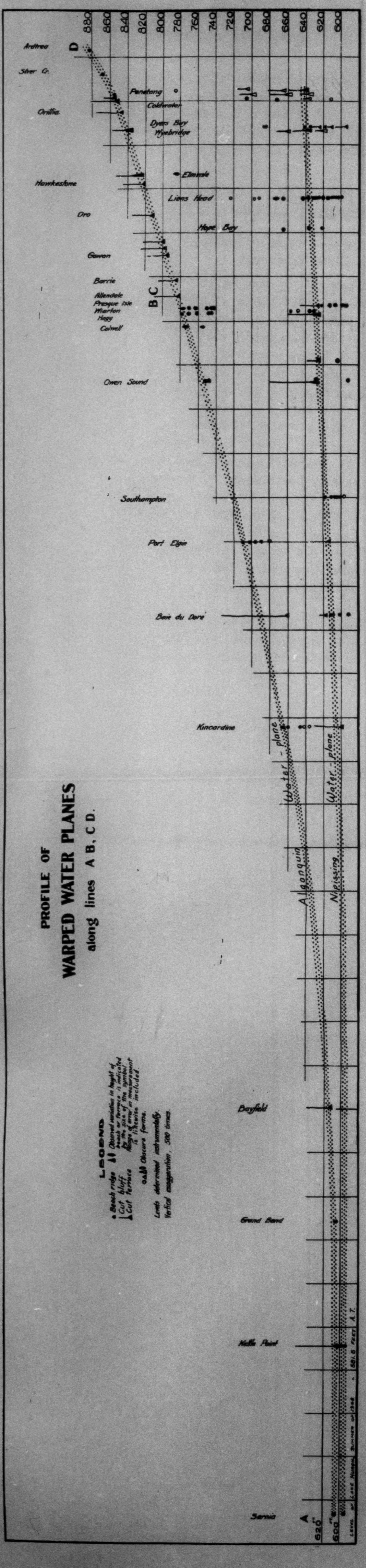
[1] For a more detailed presentation of this idea see Jour. Geology, vol. 16, 1908, figs. 4 and 5, pp. 474-475.

Fig 2



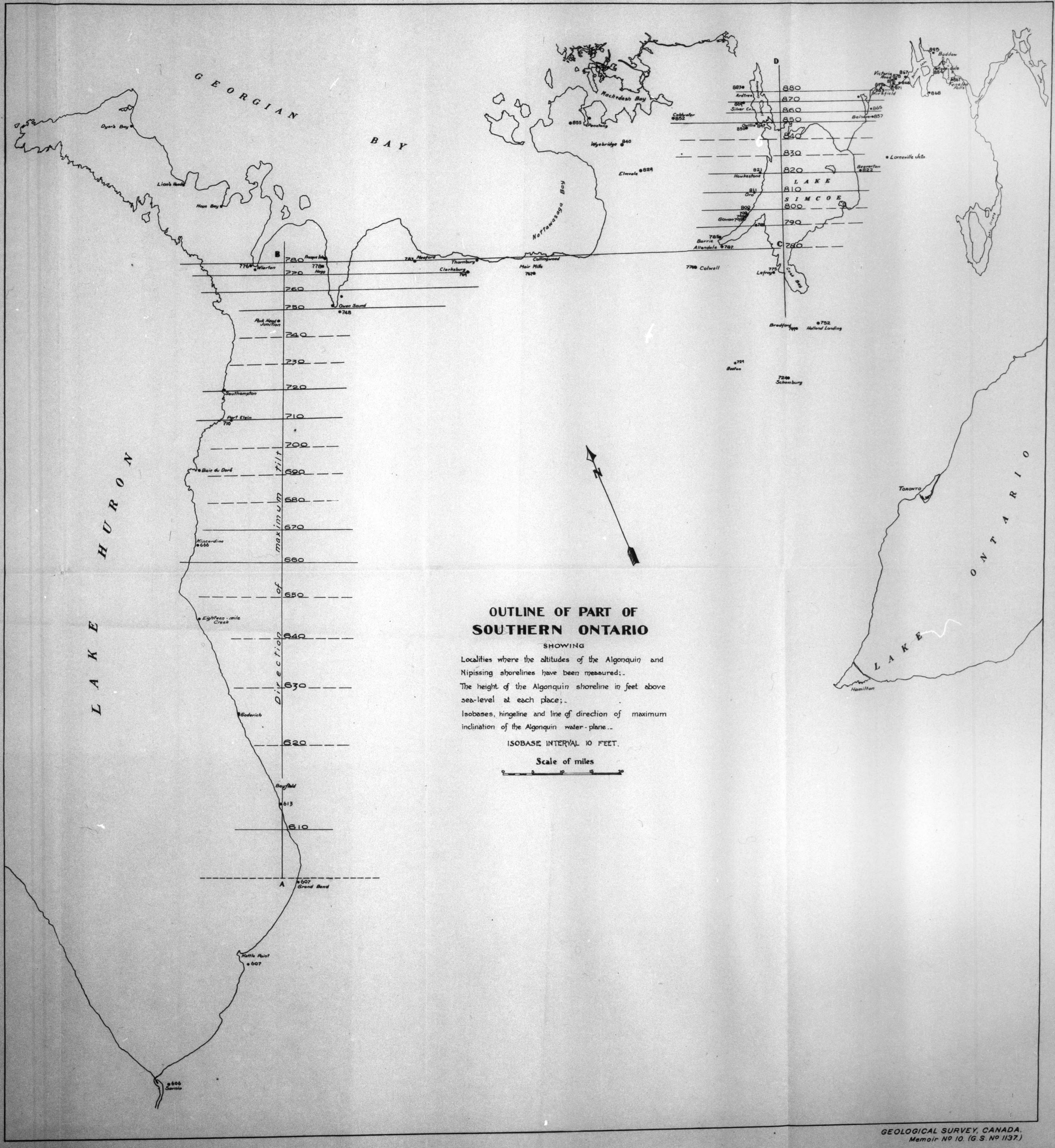
PROFILE OF
WARPED WATER PLANES
along lines A B, C D.

LEGEND

- • Beach ridge
- | Cut bluff
- ▲ Cut terrace
- ‖ Observed variation in height of beach or terrace is indicated by the size of the symbol. Range of error in measurement is likewise included.
- ∘ △ Obscure forms.

Levels determined instrumentally.
Vertical exaggeration, 500 times.

Fig. 1


GEORGIAN BAY
LAKE HURON
LAKE SIMCOE
LAKE ONTARIO
Nottawasaga Bay
Matchedash Bay
Cook Bay
N
Direction of maximum tilt
A
B
C
D
880
870
860
850
840
830
820
810
800
790
780
770
760
750
740
730
720
710
700
690
680
670
660
650
640
630
620
610
Dyer's Bay
Lion's Head
Hope Bay
Presque Isle
Wiarton
Hogg
Owen Sound
Park Head Junction
Southampton
Port Elgin
Baie du Doré
Kincardine
Eighteen-mile Creek
Goderich
Bayfield
Grand Bend
Kettle Point
Sarnia
Meaford
Thornbury
Clarksburg
Collingwood
Mair Mills
Penetang
Wyebridge
Elmvale
Coldwater
Ardtrea
Silver Cr.
Orillia
Hawkestone
Oro
Gowan
Barrie
Allendale
Colwell
Lefroy
Bradford
Holland Landing
Beeton
Schomberg
Victoria Road
Kirkfield
Bolsover
Beaverton
Lorneville Jct.
Toronto
Hamilton

OUTLINE OF PART OF
SOUTHERN ONTARIO

SHOWING

Localities where the altitudes of the Algonquin and Nipissing shorelines have been measured;-

The height of the Algonquin shoreline in feet above sea-level at each place;-

Isobases, hingeline and line of direction of maximum inclination of the Algonquin water-plane.-

ISOBASE INTERVAL 10 FEET.

Scale of miles

0 5 10 15 20

Orillia to Bracebridge........	4·25 feet per mile.
Bracebridge to Huntsville......	1·00 foot "
Huntsville to Trout Creek......	6·90 feet "
Trout Creek to North Bay......	2·80 feet "

(descent towards the northeast).

The chief argument against the correlation assumed in this table is the fact that the Nipissing water plane seems to continue to ascend uniformly northeastward at least as far as North Bay. It would be strange, indeed, if the older, higher, Algonquin plane descended over a part of the same district, viz., northeast of Trout creek.

DESCRIPTION OF MAPS AND PROFILES SHOWING THE NATURE OF THE DIFFERENTIAL UPLIFTS.

Map of Southwestern Ontario, showing Isobases of the Algonquin Beach.

Fig. 1 is an outline map of the region between Sarnia and Orillia, which includes all the localities where measurements were made in 1908 as far north as the Archæan border. On this map is put the altitude of the Algonquin beach in feet above sea-level at each place where its identity has been fixed. Through certain points where the Algonquin shoreline now stands at approximately the same altitude it is possible to draw lines of equal deformation—'isobases.' For instance, a line connecting points where the beach now stands at 780 feet above sea-level, can be drawn very satisfactorily with reference to the observations at Wiarton (777 feet), Hogg (778 feet), Meaford (783 feet), and Allandale (782 feet). An isobase for 770 feet, if drawn through Clarksburg (769 feet) parallel to the 780 ft. line, harmonizes almost perfectly with the measurements at Mair Mills (767 feet), Coldwell (774 feet), and Lefroy (775 feet). It must be kept in mind, however, that no beach nor shore terrace was absolutely level when first constructed, but it varied a few feet in height; consequently a variation of 5 or 6 feet in the measurements need not be regarded as a disturbing factor in drawing isobases. Slight discordances are to be expected.

A whole set of isobases like these two can be constructed. If conditions were ideal, each one would pass through those points where the Algonquin beach stands at the altitude which the line represents (e.g., 750 feet), and would pass by other points (e.g., 749 feet and 755 feet), at distances appropriate to the amount by which the shoreline is higher or lower than the altitude of the line. Allowing, however, an original variation of 5 or 6 feet, as just explained, we can use some discretion in avoiding abrupt turns or curves in drawing the lines. A little experimenting soon shows that if the isobases are drawn nearly parallel to these well-established lines of 770 and 780 feet, they agree (within 3 or 4 feet above and below) with every measurement. The lines in Fig. 1 have been drawn in this way for every 10 feet of altitude.

It is apparent at a glance that the isobases are farther apart in the southern part of the map than in the middle or northern part. This expresses the fact that the plane of the Algonquin shoreline is less steeply inclined in the former than in the latter. The increase in tilt rate as one goes farther and farther north is thus graphically shown.

The trend of the isobases where they have been fixed with the greatest degree of precision, is 21 degrees south of east. Since this is the direction of no difference of elevation of the Algonquin beach, it is exactly perpendicular to the direction of maximum inclination of that beach. The latter direction, indicated by the words 'Direction of maximum tilt,' runs, therefore, about N 21° E. Its course doubtless varies a little in different parts of the region, but only a few degrees. The course of the isobases, direction of tilt, and rate of tilt are more thoroughly established over the south shore of Georgian bay and Lake Simcoe than farther south; for east of Lake Huron localities are far apart and on nearly a straight line. The direction there is based largely upon knowledge of the conditions over Lake Michigan and the west side of Lake Huron.

On this map isobases have not been extended east of Kirkfield, because of the uncertainty there of distinguishing between the Algonquin beach and the shoreline of lower origin along the course of the ancient outlet.[1] Over the district as a whole, however, the water plane slants with remarkable regularity.

Profile of the Warped Water Planes in Southwestern Ontario.

With this map as a basis for locating stations, a profile (Fig. 2) has been drawn to show the Algonquin beach and those below it.

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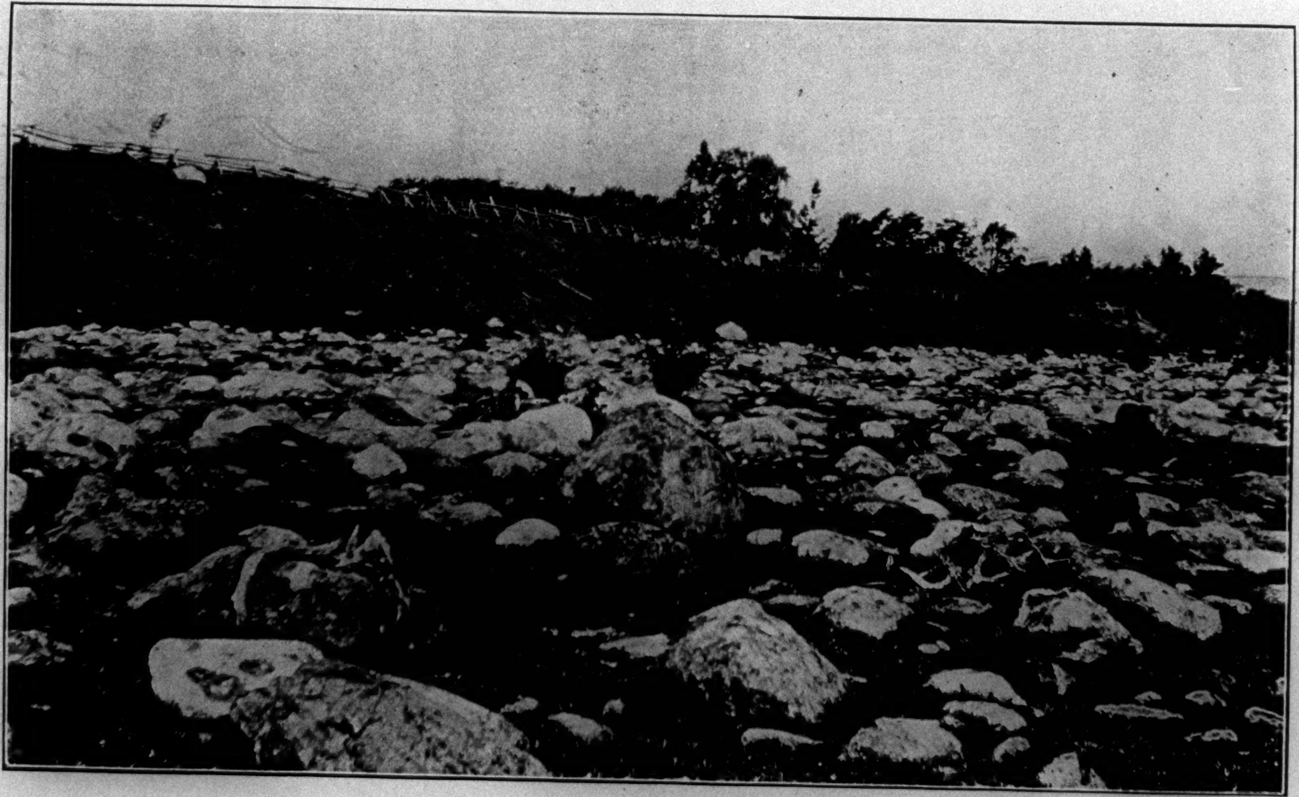
[1] See p. 32.



Nipissing bluff and boulder pavement, near Meaford, 629 feet.

2652—p. 36.

Upon the line of maximum inclination was plotted the position of each station between Sarnia and Wiarton where measurements had been made. Each point was then transferred to a sheet of co-ordinate paper, on which distances from left to right represent distances from south to north (S 21° W to N 21° E). The data from the Simcoe district, between Allandale and Orillia, instead of being plotted in a separate profile, were simply added to the first, the two ends, at Allandale and Wiarton, nearly coinciding. Certain measurements, e.g., Meaford, Clarksburg, and Mair Mills, were not plotted, because they are so far off the two lines of reference for the two halves of the profile, and because they would simply confirm the other data without adding new elements to the profile. The measurements at the six localities in the Simcoe basin south of Allandale, chiefly by Mr. Taylor and Mr. Johnston, do not appear, because the tilt rate there is somewhat flatter than at corresponding altitudes on the Sarnia-Wiarton profile. The measurements in the Kirkfield-Trent Valley district are also omitted, and for the same reason for which the isobases were not extended among them in Fig. 1. The three measurements north of Orillia, by Mr. Taylor and Mr. Johnston, on the other hand, have been added to the north end of the profile, in order to show the abrupt increase of tilt near the border of the Archæan highlands. The results of wye-leveling at Penetanguishene and Coldwater, though these places are rather far off the profile line, were added for the same reason. The data from the Saugeen peninsula are also embodied in the profile.

Using these points as ordinates, both the Algonquin and the Nipissing water planes have been reconstructed. The various symbols for the measurements indicate whether the shoreline in any case is a beach or a cut terrace, whether an acceptable or an obscure form. If its height is unusually variable or if the measurement involves perhaps more than the usual small amount of error, the symbol is lengthened vertically to cover the possibility. And finally, the two water planes are restored not as lines but rather as bands, 6 feet broad according to the vertical scale, so as to include such small discordances as must be expected because of the original variation in height and of the usual though slight errors in measurement. Thus constructed, the profile shows plainly enough, with hardly an exception, which is the Algonquin and which the Nipissing beach at any locality. It brings out clearly the change in steepness of tilt of the Algonquin beach southward to the point of complete flattening south of Bayfield, and the more gentle but equally simple inclination of the lower, Nipissing shoreline.

General Map of the Great Lake Region, showing Isobases of the Algonquin Beach.

It remains now to fit in the data from Ontario (Fig. 1) with the data previously collected on the west side of Lake Huron and around Lake Michigan. This has been done in Figs. 3 and 4.

In Fig. 3, the approximate position of the Algonquin shoreline is indicated by a heavy line. The data on the west side of Lake Michigan are taken from the writer's survey of 1905. Everywhere else the outline of the extinct lake has been furnished by Mr. Taylor. Wherever there is uncertainty as to the identity of the Algonquin beach (as in the southern half of the Lake Michigan basin, where it is not easy to distinguish it from the Nipissing), or wherever the Algonquin shoreline has not been explored, the line in Fig. 3 is broken. Many stretches of the ancient shoreline are missing because of recent cliff recession along the present lake border, as the map shows. The localities where the exact altitude of the Algonquin beach, in feet above sea-level, is indicated in Fig. 3, are as follows:—

On the west side of Lake Michigan: 273 feet, Burnt Bluff, Mich.; 680 feet, Washington Harbour; 660 feet, Death Door; 648 feet, Sister Bay; 641 feet, Bailey Harbour; 637 feet, Jacksonport; 620 feet, Sturgeon Bay; 616 feet Brussels; 611 feet, Cormier; 610 feet, Algoma; 607 feet, Two Rivers, Wis.; 605 feet, Evanston, Ill.

In the Straits of Mackinac and along the east side of Lake Michigan: 863 feet, Hessel; 812 feet, Mackinac island; 746 feet, Cross village; 731 feet, Beaver island; 709 feet, Harbour Springs; 698 feet, Burgess; 674 feet, Norwood; 658 feet, Northport; 648 feet, North Manitou island; 647 feet, Leland; 640 feet, Sutton Bay; 633 feet, Elk Rapids; 619 feet, Traverse City; 612 feet, Platte Lake; 603 feet, Spring Lake; 605 feet, Holland, Mich.

On the west side of Lake Huron (data furnished by Mr. Frank Leverett, Dr. A. C. Lane, and members of the Michigan Geological Survey): 713 feet, Alpena; 642 feet, Greenbush; 617 feet, Tawas City; 610 feet, Omer; 607 feet Worth; 610 feet, Kawkawlin; 603 feet, Bay City; 605 feet, Holland, Mich.

East of Lake Nipissing, Georgian bay, and Lake Huron: 1178 feet, North Bay; 1,221 feet, Trout Creek; 1,007 feet, Huntsville; 989

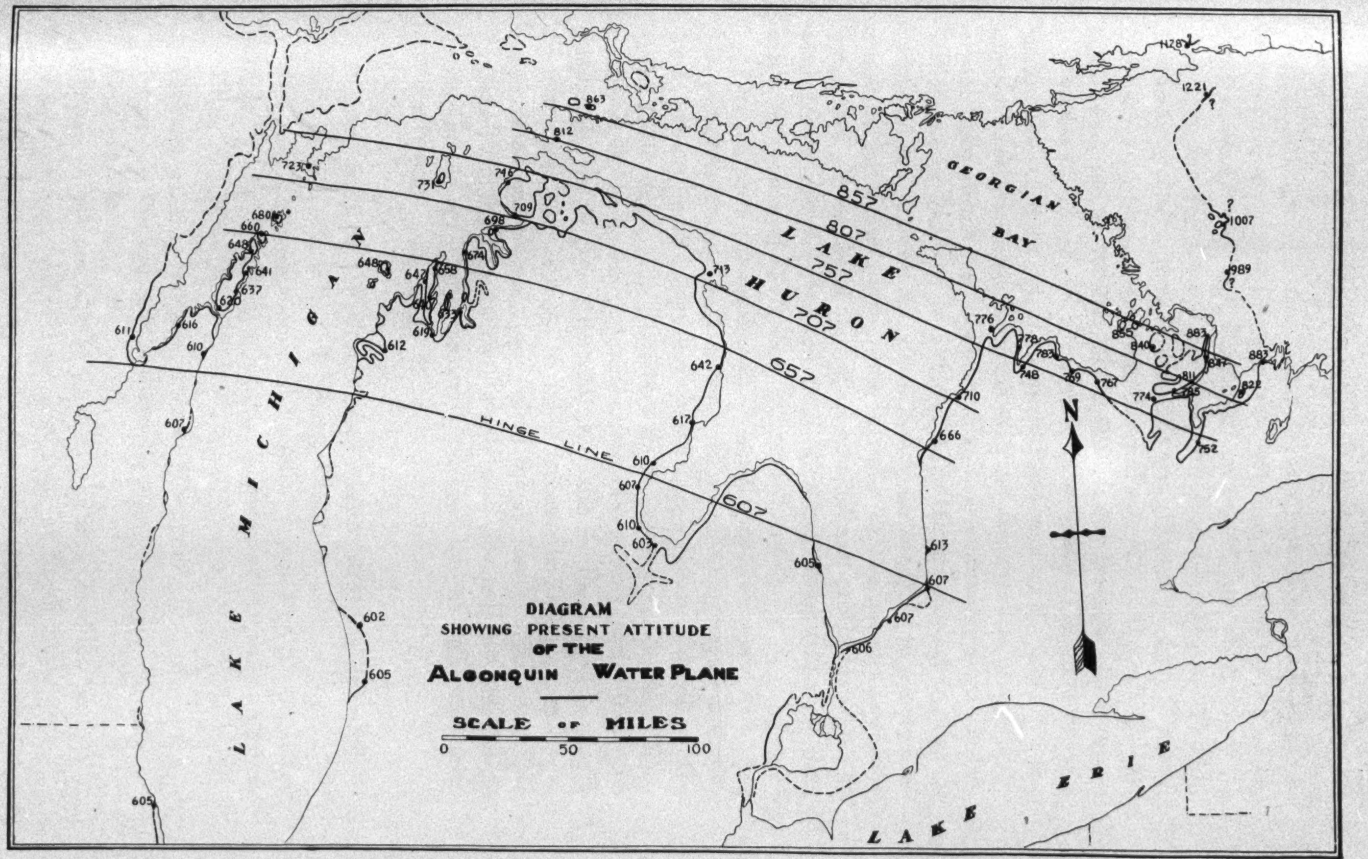


DIAGRAM
SHOWING PRESENT ATTITUDE
OF THE
ALGONQUIN WATER PLANE
SCALE OF MILES
0
50
100
LAKE HURON
GEORGIAN BAY
LAKE MICHIGAN
LAKE ERIE
N
HINGE LINE
857
807
757
707
657
607
1128
1221
1007
989
863
812
723
731
746
709
698
680
660
648
641
637
620
616
611
610
607
605
602
648
642
658
674
619
612
713
642
617
610
607
610
603
605
613
607
606
710
666
776
778
783
748
769
767
774
785
811
840
855
883
847
883
822
752

Fig. 3.

2652—p. 38.

feet, Bracebridge; 883 feet, Kirkfield; 822 feet, Beaverton; 752 feet, Holland Landing; 883 feet, Ardtrea; 847 feet, Orillia; 811 feet, Oro; 785 feet, Barrie; 855 feet, Penetanguishene; 840 feet, Wyebridge; 774 feet, Colwell; 767 feet, Mair Mills; 769 feet, Clarksburg; 783 feet, Meaford; 748 feet, Owen Sound; 778 feet, Hogg; 776 feet, Wiarton; 710 feet, Port Elgin; 666 feet, Kincardine; 613 feet, Bayfield; 607 feet, Grand Bend; 607 feet, Kettle Point; 606 feet, Sarnia, Ont.

The condition of the Algonquin water plane (the direction and spacing of its isobases) in Ontario is so much like that over the northern half of Lake Michigan that the connexion of the isobases across Lake Huron, as shown in Fig. 3, is reasonably sure. A few measurements from the west side of Lake Huron, selected from those by Mr. Frank Leverett, Mr. Taylor, and especially from members of the Michigan State Survey, aid in restoring the isobases over this broad lake. It is hoped that more detailed and precise data will at some future time be gathered from Michigan, to fix still more definitely the course of the lines.

Two features shown in Fig. 3 should not be overlooked. (1) The widespread uniformity of the uplifts. The movements were not local, but regional, covering an area many times as large as the Great Lake region. And nowhere do the movements seem to have consisted in irregular dislocations or sharp warpings, unless the facts from the Kirkfield district, near the Archæan border, should prove to be of that nature. (2) The isobases in Ontario and across Lake Huron run roughly parallel to the Archæan boundary. This suggests that the 'Laurentia' which was elevated so many times during the history of the continent has been the centre of this most recent elevation.

General Map of the Great Lake Region, showing Isobases of the Nipissing Beach.

This map was constructed in the same way as Fig. 3. On it the altitude of the Nipissing shoreline is given at fifty-four selected localities, as follows:—

Fourteen on the west side of Lake Michigan.
Twenty on the east side of Lake Michigan.
Four near Saginaw bay.
Fifteen on the east side of Lake Huron and Georgian bay.
One at the east end of Lake Nipissing, at North Bay.

The four measurements near Saginaw bay are selected from a number of wye-level measurements obtained by the Michigan Geological Survey. The other fifty were made by the writer during the summers of 1905, 1907, and 1908.

An equally complete set of measurements of the Nipissing shoreline on the west side of Lake Huron is very desirable. Most of the measurements thus far collected in that field are hand-level or aneroid determinations. Recently leveling has been done on the beaches from Saginaw bay northward by Mr. W. M. Gregory for the Michigan Geological Survey, but these have not yet been published.

It is not possible to draw the isobases with as much precision for the Nipissing water plane as for the Algonquin; for the Nipissing is much less steeply inclined. The isobases on that account are farther apart, and the variation of 5 or 6 feet in the original construction of the beaches and terraces becomes a more prominent element. For instance, the isobase for 630 feet may fail to pass through a 630 ft. point by a distance of several miles—apparently a bad case of discordance, although in reality the 630 ft. beach may be only 3 feet higher or lower than the isobase would require. It should be remembered that the isobases represent averages, and do not need to conform absolutely to the points through and between which they pass. In this respect they are like contour lines on a map, which to express topographic character ignore small and meaningless irregularities of slope. The irregularities of altitude of the Nipissing water plane ignored by the isobases are slight, and referable in all cases to local extremes in construction of beaches or terraces along the ancient shore.

The tilt rates of the Nipissing plane are approximately as follows:—

Sarnia to Grand Bend (35 miles)..	horizontal.
Grand Bend to Kincardine (57 miles)..	0·11 feet per mile.
Kincardine to Port Elgin (21 miles)..	0·57 "
Port Elgin to Dyers Bay (47 miles)..	0·57 "
Dyers Bay to North Bay (115 miles)..	0·49 "

The rather close agreement of tilt rates in the last 183 miles is striking, and the more so when it is realized that some allowance must be made, in the stretch between Dyers Bay and North Bay, for the great distance, and the probability of a slight change of direction of inclination within that 115 miles. If the Nipissing at North Bay

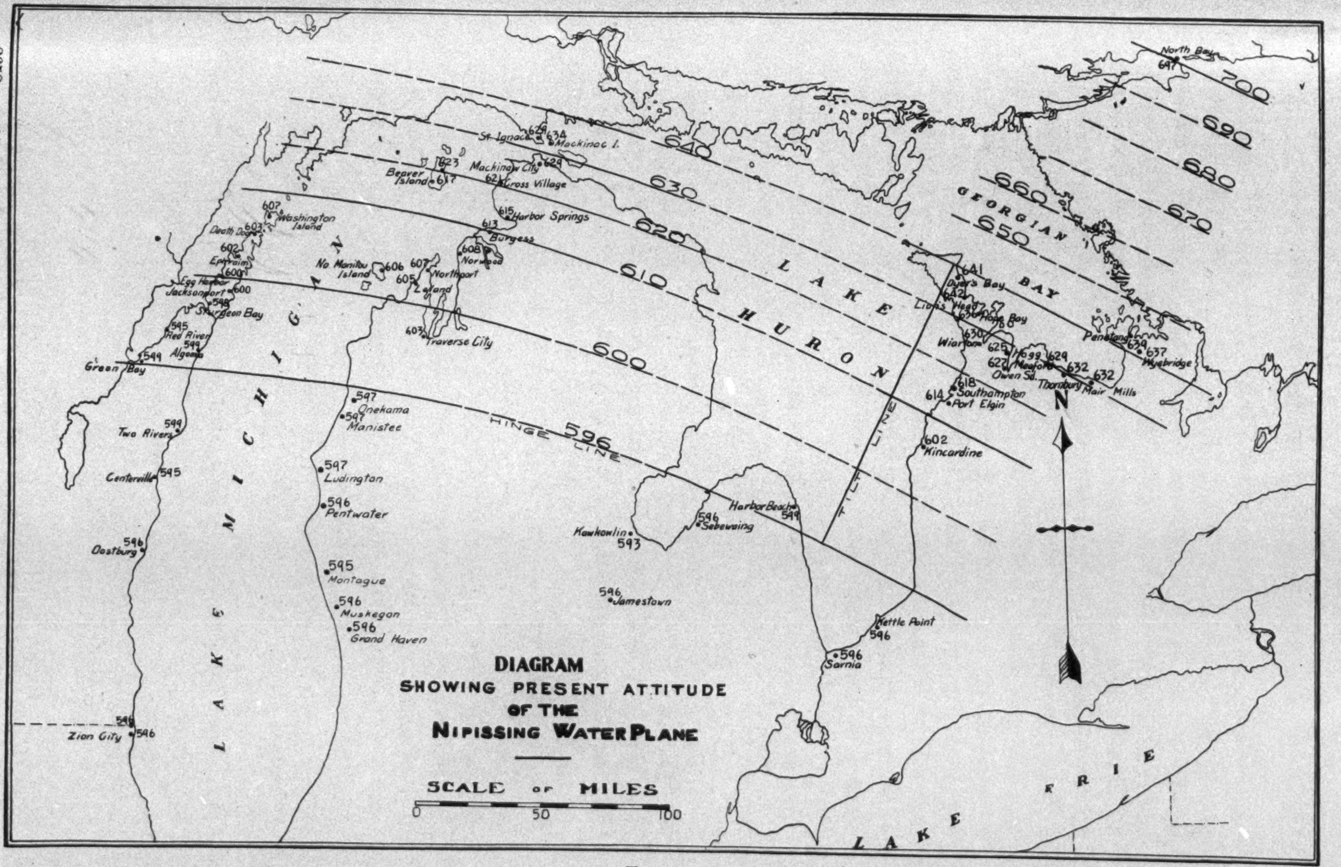


DIAGRAM
SHOWING PRESENT ATTITUDE
OF THE
NIPISSING WATER PLANE
SCALE OF MILES
0
50
100
N
LAKE HURON
GEORGIAN BAY
LAKE MICHIGAN
LAKE ERIE
700
690
680
670
660
650
640
630
620
610
600
596 HINGE LINE
TILT LINE
North Bay 647
St. Ignace 629
634 Mackinac I.
623
Beaver Island 617
Mackinaw City 629
621 Cross Village
615 Harbor Springs
613 Burgess
608 Norwood
607 Northport
605 Leland
603 Traverse City
No Manitou Island 606
607 Washington Island
Death Door 603
602 Ephraim
600
Egg Harbor
Jacksonport 600
598 Sturgeon Bay
595 Red River
599 Algoma
599
Green Bay
599 Two Rivers
Centerville 595
596 Oostburg
596 Zion City 596
597 Onekama
597 Manistee
597 Ludington
596 Pentwater
595 Montague
596 Muskegon
596 Grand Haven
Kawkawlin 593
596 Jamestown
596 Sebewaing
Harbor Beach 599
Kettle Point 596
596 Sarnia
602 Kincardine
614
618 Southampton
Port Elgin
641 Dyer's Bay
642 Lion's Head
636 Hope Bay
630 Wiarton
625
627 Owen Sd.
Hogg 629 Meaford
632 Thornbury
632 Mair Mills
Penetang 639
637 Wyebridge

FIG. 4.

were only 9 feet higher, the tilt rate for this last stretch would be 0·57 feet per mile, as in the district just south of Dyers Bay. Within reasonable limits of observation, therefore, the inclination of the Nipissing plane between Georgian bay and Lake Nipissing is the same as that farther south—about half a foot to the mile.

The bearing of this on the unsettled question of the identity of the Algonquin beach at North Bay, Trout Creek, Huntsville, and Bracebridge has already been mentioned. The Algonquin plane was once thought to be irregularly warped, here in the highlands, even descending northward between Trout Creek and North Bay at a rate of 2·80 feet per mile (*see* p. 35). If this were the case, the warping movements that followed the Algonquin stage must have been unlike the even tilting that followed the Nipissing stage. Such a contrast between the post-Algonquin and post-Nipissing deformations is not impossible, but it is much more likely that the former movements, like the latter, were broad, even uplifts.

CONCLUSIONS.

Taking up the conclusions in the same order in which they were outlined earlier in the paper, we may now discuss them in the light of the evidence that has been presented.

(1) The measurements of altitude are in most cases wye-level measurements. Although even these involve certain errors, due partly to the choice of a point to be measured (crest of a beach ridge, inner edge of a cut terrace, etc.), and partly to the process of leveling itself, and to the use of lake level as a base, the errors are of small range. There is an uncertainty amounting to a few inches or perhaps a foot, as compared with an uncertainty of 5 or even 10 feet in the aneroid or hand-level measurements. In the case of the Nelson beach at North Bay, a correction of 40 feet was made; but this is very exceptional.

The number of localities at which the Algonquin beach was measured is rather small for so large a region; but only five weeks were available. There are, to be sure, long gaps on the east side of Lake Huron, e.g., forty-four miles between Bayfield and Kincardine. This gap and other large ones are due chiefly to the scarcity of preserved fragments of the Algonquin beach along the cliffed shore. Yet the reconstruction of the beach north and south of this gap is so sure, the strength of the Algonquin shoreline at the north and south ends of the gap so marked, that no hesitation is felt by the writer in making the correlation across the space of more than forty miles. Whether the correlation needs a greater number of measurements or not can be judged best from the profile, Fig. 2.

(2) The construction of isobases on the deformed Algonquin plan in Ontario, as shown in Fig. 1 and discussed on pages 35 and 36. shows the attitude of the warped surface in the same way in which contours show the slope of the ground. The straightness and parallelism of the lines expresses the remarkable uniformity of direction of inclination of the plane. Since isobases of a uniform interval, 10 feet, have been chosen, the variation in their spacing shows at a glance the change in rate of tilt from northeast to southwest. The same facts appear in the isobases of the map of the greater region of which Ontario is a part (Fig. 3). The absence of local irregularities in the differential movements over the whole southern part of the Great Lake region is most surprising.

In the restoration of a warped water plane over so great an area, one finds reasonable hope that future studies elsewhere may extend the reconstruction not simply of this plane and its contemporaries, but of earlier and later ones over the whole region which partook of the differential uplifts.

(3) That the strong Algonquin beach was formed during the activity of the Algonquin river as an outlet is at last established by the correlation of the 883 ft. beach at Kirkfield with the Algonquin beach at Orillia and just north of it. It now appears that Mr. Taylor's interpretation of the Algonquin was correct; it is a 'two-outlet' beach, begun at a lower level when the Algonquin river was the sole outlet, carried up by the rising waters that accompanied the uplift of this outlet, and finished while the discharge was divided between the Algonquin river and the St. Clair outlet. Later deformations have raised the whole Algonquin shoreline and the Trent outlet out of water.[1]

(4) The direction of tilt of the Algonquin plane in Ontario, measured perpendicularly to the isobases, is approximately N 21° E. The rate of tilt, as already stated, varies as one goes northward. From a condition of horizontality at Grand Bend, the plane rises towards the northeast with a rate of about 1·43 feet per mile in the first forty-four miles (to Kincardine), 2·10 feet per mile in the next

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[1] See Jour. Geology, vol. 16, 1908, p. 475, fig. 5.

twenty-one miles (to Port Elgin), and 2·44 feet per mile in the next twenty-seven miles (to Wiarton). These tilt rates, it should be remembered, are averages for rather long stretches, in each of which there is a much steeper slant in the northern than in the southern portion. For instance, over Wiarton the rate is not 2·44 feet per mile, but 3·60 feet per mile. This appears from a comparison of the measurements at Owen Sound, Hogg P.O., and Wiarton.

Over the southern part of the Simcoe basin the same isobases as those in the Owen Sound–Wiarton district are farther apart; i.e., the tilt rate just south of Lake Simcoe is about 2·88 feet per mile instead of 3·60 feet per mile, although the Algonquin beach has been lifted to the same altitude in these two districts. It is a case of warping as contrasted with tilting; but the difference is not so pronounced as to seriously disturb the conception of isobases that run approximately parallel and mark an uplift of extraordinary uniformity.

Over the Lake Simcoe district itself the rate of tilt is about 3·25 feet per mile. North of Orillia the accurate pocket level measurements by Taylor and Johnston, and the leveling at Kirkfield, indicate a tilt rate of 6 feet per mile for the district close to the border of the Archæan highlands. Dr. Spencer's average tilt rate of 4·1 feet per mile over Lake Simcoe agrees with the figures here given; for his is the rate for a longer stretch than those here measured. That is to say, Dr. Spencer's average tilt rate of 4·1 has here been analysed into a northward ascent that changes from 3·25 feet to 6 feet per mile.

(5) That the Algonquin water plane does not continue to slant southward beyond Grand Bend, dipping beneath Lake Huron, as it was once believed to do, is now evident from these facts. (*a*) The reconstructed plane, as shown in Fig. 2, flattens rapidly between Kincardine and Bayfield. A natural continuance of this flattening would produce perfect horizontality before the plane could descend to the lake level at Sarnia. (*b*) The 607 ft. beach at Grand Bend is a distinct, gravelly beach. It cannot be correlated with any beach of the district that stands above the Algonquin; it is much too close to the level of the Algonquin for that. The cut bluff and terrace at Kettle point are very strong. They extend for several miles along the shore. Such strength is characteristic of the Algonquin over the entire region, but not characteristic of any other except the Nipissing. The 606 ft. beach at Sarnia, also, appears to register a stage

of long duration. The Algonquin plane, if extended south from Bayfield, does not have to flatten abruptly to coincide with a horizontal plane at 606 feet at Grand Bend; but it passes gradually and naturally into it. (*c*) Data gathered from the west side of Lake Huron by members of the Michigan Geological Survey,[1] and by Mr. Taylor and Mr. Leverett, indicate that the Algonquin beach is approximately horizontal at 607 feet around the south end of Saginaw bay. If, then, we draw a line across Saginaw bay and Lake Huron, so as to pass nearly through Omer, Bad Axe, and Grand Bend, this line will separate the district where the Algonquin is within 2 or 3 feet of 607 from the district where it plainly rises towards the northeast.

(6) The reconstruction thus secured for the southern part of the Lake Huron district is exactly comparable to the reconstruction of the Algonquin plane in eastern Wisconsin.[2] The reconstruction in Wisconsin was based on fewer measurements than this in Ontario, because the Algonquin beach has been very generally destroyed along the west side of Lake Michigan. The conclusion as to horizontality there, however, is strongly supported by measurements on both sides of Lake Michigan, which show that two higher beaches (the Glenwood and Calumet beaches of Lake Chicago) are horizontal everywhere south of a line through Milwaukee, Wis., and Grand Haven, Mich.[3] If these higher beaches have not been warped or tilted out of position, the later, lower Algonquin surely has not been deformed. The horizontality of the Algonquin plane north of Milwaukee is based on the horizontality of a strong terrace at 596 feet (the Nipissing), a supposed Algonquin beach at Two Rivers, Wis., at 607 feet, and the flattening of the Algonquin plane as it approaches the altitude of 607 feet on both sides of Lake Michigan.

Data from both lake basins, therefore, indicate that the Algonquin plane stands horizontal at an altitude of 607 feet south of a line that passes approximately through Green Bay and Kewaunee, Wis., a few miles north of Frankfort, Mich., through Bad Axe, Mich., and a few miles north of Grand Bend, Ont.

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[1] Including wye-level measurements plotted on the map, Figure 3. These are taken from: 'Geological Rept. on Huron County,' A. C. Lane, Geol. Survey, Michigan, vol. 7, part 2, 1900, pp. 47-51 and 75-85; 'Geological Rept. on Bay Co.,' W. F. Cooper, Geol. Survey, Michigan, Ann. Rept., 1905, pp. 135-426; and 'Pleistocene Beaches of Saginaw Co.,' W. F. Cooper, Michigan Acad. Sci., 10th Ann. Rept., 1908, pp. 90-98.

[2] See 'Abandoned shorelines of eastern Wisconsin.' Bull. Wisconsin Geol. and Nat. Hist. Survey, No. 17, 1907, pp. 101-103, 109-110.

[3] Jour. Geology, vol. 16, 1908, p. 164.

The data from the east side of Lake Michigan, as already noted, was not decisive as to the height of the Algonquin plane, whether it is horizontal at 607 feet or at 596 feet. There seem to be distinct shorelines at both levels, although south of Frankfort the lower one, usually a cut bluff, is the only one that was discovered. The question thus left open after the survey along the east side of Lake Michigan in 1907 seems, therefore, to have been settled by the identification of the Algonquin beach at 607 feet in the extreme southwestern part of Ontario.

(7) A horizontality so widespread as this of the Algonquin plane, which extends from southwestern Ontario to Wisconsin and Illinois without a variation of more than 6 or 7 feet in altitude, is no less surprising than it is significant. It seems to mean simply that the beach and the region in question have suffered neither uplift nor depression since Algonquin time. One can hardly conceive of an uplift or a depression going on over so wide an area without producing a measurable variation of height in the water plane—a score or two of feet, at least. This is especially true in view of the fact that a differential uplift has clearly occurred over the northern part of the lakes. The conclusion seems unescapable that all around the southern ends of Lakes Huron and Michigan the Algonquin beach stands to-day at precisely the altitude at which it stood when it was formed, namely, at about 607 feet above the sea.[1]

(8) Here, then, we seem at last to have a real plane of reference from which to measure the altitudes of other points in the Great Lake region in late glacial times. Wherever the Algonquin beach can be found and measured we have only to subtract 607 feet from its altitude to determine how much the region has been raised since the beach was formed. For instance, the Algonquin beach at Penetanguishene stands now at an altitude of 855 feet. When formed, it stood approximately at 607 feet. The Penetanguishene peninsula, therefore, stands higher to-day by about 250 feet than it stood during the formation of the Algonquin beach. In the same way, if we only knew with certainty that the Nelson beach at North Bay (1178 feet) were the Algonquin, we would be able to reach the conclusion that the

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[1] This line of reasoning was used by the writer in a paper before the American Association for the Advancement of Science at Hanover, N.H., in July, 1908. An abstract of the paper 'The attitude of the Algonquin beach, and its significance,' is in 'Science,' New Series, vol. 28, Sept. 18, 1908, pp. 382-383. Since then the work in Ontario has strengthened the argument by more fully establishing the horizontality of the Algonquin beach.

Nipissing pass stands to-day (1178 feet–607 feet) 571 feet higher than it did in Algonquin time. And since the floor of this pass is to-day only about 690 feet above sea-level, it would appear that it was formerly only 119 feet or so above the sea. We could thus determine the probability or improbability of a marine invasion of the Great Lake basins from the northeast when the ice sheet first withdrew. But until the correlation of the Algonquin beach is caried that far, the use of the 607 ft. datum plane will be limited chiefly to the middle and southern parts of the Great Lake region.

(9) Attention has already been called to a rapid steepening of tilt on the Penetanguishene peninsula north of Orillia and near Kirkfield, that is, within a few miles of the border of the Archæan highlands. The tilt rate here appears to be 6 feet per mile, although a few miles south of here it becomes 4 feet per mile. The profile (Fig. 2) brings out plainly the abruptness of this change. One naturally looks for other facts which would indicate that the direction and rate of tilt were in some way related to the outline of the Archæan area. The rough parallelism between the isobases across Lake Huron and the Province of Ontario and the edge of the highlands appears to be a fact of that sort. It suggests that the post-Algonquin uplifts were repetitions of those more remote uplifts which kept 'Laurentia' above sea-level during the greater part of geologic time. Will it be found, after all, that the isobases of post-glacial deformations in North America encircle the Laurentian highlands as Baron DeGeer's isobases encircle the Scandinavian highlands?[1] Even if these movements were set going by the removal of the heavy ice sheet, were they not guided or even controlled by the same great elements of internal structure which determined the outlines of the Laurentian highlands?

(10) Observations around Balsam and Cameron lakes show that even in these small basins there is a distinct shoreline which is either the extension of the Algonquin beach itself, or its contemporary in a chain of pools along the Algonquin river. A comparison of the five or six measurements in this district (*see* p. 32) shows that if this shoreline is the Algonquin it has suffered local warping of an unusual sort. Nowhere else in the Great Lake region where detailed work has been done has a clear case of local warping of the Algon-

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[1] Gerard DeGeer: 'Quaternary changes of level in Scandinavia. Bull. Geol. Soc. America, vol. 3, 1892, p. 67; and 'On Pleistocene changes of level in eastern North America.' Proc. Boston Soc. Nat. Hist., vol. 25, 1892, pp. 454-477.

quin beach been discovered. The alternative, as stated on page 31, is that this shoreline on Balsam and Cameron lakes marks the outline of a chain of lakes between rapids on the ancient outlet; that in Balsam lake the water plane was originally lower than in Lake Algonquin, and in Cameron lake it was still lower. A detailed survey of the raised beaches around these lakes of the Trent system, Balsam, Cameron, Sturgeon, and Pigeon lakes, ought to settle the question. Here appears to be an opportunity to carry the inclined plane of post-Algonquin deformations from Lake Algonquin across the Kirkfield pass and down the old outlet nearly to the Ontario basin, where it could be compared with the plane of the supposed contemporary, Lake Iroquois. Chances for such correlation of an ancient water plane in one basin with that in another are rare if not unknown elsewhere.

(11) At four localities in the Archæan highlands east of Georgian bay (Bracebridge, Huntsville, Trout Creek, and North Bay) the altitudes of raised beaches have been secured with the wye-level. So far apart are these localities that it is doubtful whether the strong beach that lies at or near the upper limit of the series at each place is the same Algonquin beach that has been correlated as far north as Kirkfield. The outlook for satisfactory correlation in the highlands is not promising, for several reasons. The shores here were very irregular, allowing only locally an opportunity for strong wave action. The materials composing the shores did not lend themselves as readily to terrace and beach construction as the glacial drift and bedded limestones of more southerly districts. The Algonquin beach north of Kirkfield is probably not a single, strong shoreline, but a series of beaches, because during the uplifts which raised the Trent outlet up to the level of the Port Huron outlet the northern district was emerging while the southern district was being drowned. Somewhere in this northern highland region each beach probably fades away as it approaches the position of the ice border at that stage. This might be a great obstacle to tracing the Algonquin and other high-level beaches as far as North Bay. The correlation of the 989 ft. terrace at Bracebridge, the 1007 ft. one at Huntsville, the 1221 ft. beach at Trout creek, and the 1178 ft. beach at North Bay, as points on a single water plane—the northern extension of the Algonquin plane—does not seem justified.

(12) The isobases of post-Nipissing deformation (Fig. 4) resemble those of the earlier stage (Fig. 3). They indicate a remark-

able regularity of uplift in the Great Lake region. Nor is this uniformity of tilt confined to the districts south and southwest of the Archæan area; it appears to extend as far northeast as North Bay. Herein is ground for questioning the correlation of the 'Algonquin' beaches at Bracebridge, Huntsville, Trout Creek, and North Bay, as explained in pages 40 and 41.

The widespread horizontality of the plane of the Nipissing beach at 596 feet above sea-level in the southern part of the region seems to indicate that the Nipissing Great Lakes at this stage were about 595 feet above sea-level. In other words, when these lakes last discharged in part down the Mattawa valley, the water level in the Michigan and Huron basins was about 15 feet higher than it is to-day.

The undisturbed 596 ft. plane is, therefore, a convenient plane of reference from which to measure post-Nipissing changes of altitude in the northern part of the Great Lake region.

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Bell, Robert:—

Remarks upon a paper by G. F. Wright; Bull. Geol. Soc. America, vol. 4, 1893, pp. 425-427.

Questions the former existence of an outlet through the Nipissing pass. Mentions having made profiles of the country south of Georgian bay which show terraces up to a height of 200 feet.

Chalmers, Robert:—

'Artesian borings, surface deposits, and ancient beaches in Ontario'; Can. Geol. Survey, Summary Report, 1902, pp. 270-281.

On pp. 274-276, describes shorelines of the Ontario basin, including the 'Iroquois' and higher beaches up to an altitude of 1400 feet; briefly discusses the differential uplifts which these beaches record.

Chapman, E. J.:—

'Notes on the geology of the Blue Mountain escarpment in Collingwood township, Canada west'; Can. Jour., new series, vol. 5, 1860, pp. 304-305.

'Notes on the drift deposits of western Canada and on the ancient extension of the lake area of that region'; Can. Jour., new series, vol. 6, 1861, pp. 221-229.

Comstock, F. M.:—

'Ancient lake beaches on the islands in Georgian bay'; Am. Geologist, vol. 33, 1904, pp. 311,318.

Describes terraces and beach ridges on Grant's Tomb, Beausoleil, and Tomahawk islands.

COOPER, W. F.:—

'Geological Report on Bay county'; Michigan Geol. Survey, Ann. Rep., 1905, pp. 135-426.

On pp. 349-350, gives detailed description of the Algonquin and Nipissing shorelines in Bay county, with wye-level measurements of their altitude. Data used in the construction of Fig. 3 of this report.

'Pleistocene Beaches of Saginaw county'; Michigan Acad. Sci., 10th Ann. Rep., 1908, pp. 90-98.

On pp. 96-98, gives wye-level measurements on the Algonquin and Nipissing shorelines at several localities in Saginaw county. Data used in construction of Fig. 3 of this report.

FAIRCHILD, H. L.:—

'Gilbert gulf (Marine waters in the Ontario basin)'; Bull. Geol. Soc. America, vol. 17, 1905, pp. 712-718.

Describes a beach, probably marine, which seems to descend beneath the modern Lake Ontario near Oswego, N.Y.

FLEMING, SIR SANDFORD:—

'The Valley of the Nottawasaga'; Can. Jour., vol. 1, 1853, pp. 223-226.

Describes the fossiliferous clays and sands of the valley of Nottawasaga river and shores of Nottawasaga bay, including Collingwood, Meaford, and Owen Sound.

GEER, BARON GERARD DE:—

'Quaternary changes of level in Scandinavia'; Bull. Geol. Soc. America, vol. 3, 1892, pp. 65-68.

Describes author's method of study of the upper limit of post-glacial marine submergence in Sweden; outlines conclusions already reached as to the nature and extent of post-glacial upwarpings in Scandinavia as a whole; seeks to demonstrate a casual relationship between the area recently upwarped and the area where ancient crystalline rocks are exposed.

'On Pleistocene changes of level in eastern North America'; Proc. Boston Soc. Nat. History, vol. 25, 1892, pp. 454-477.

Gives a résumé of investigations of the raised beaches of the sea-coast and inland lakes of northeastern North America, with original contributions from New England and the St. Lawrence valley; compares the differential uplifts of this region to those of Scandinavia, and discusses their cause. An isobase map of northeastern North America accompanies the paper.

GILBERT, G. K.:—

'Contributions to the History of Lake Bonneville'; U.S. Geol. Survey, 2nd Ann. Rep., 1880-1881, pp. 167-200.

On pp. 195-197 and plates 42 and 43, explains and uses curves or 'contours of deformation' to express graphically the attitude of an upwarped plane—the first application of the isobase idea to the study of raised beaches.

'The History of the Niagara river'; New York Commissioners State Reserv., Niagara, 6th Ann. Rept., 1889, pp. 61-84; (reprinted in) Smithsonian Rept., 1890, pp. 231-237.

Outlines the history of the extinct lakes of the Erie, Huron, and Ontario basins, on the basis of studies by Dr. Spencer and himself; suggests a temporary discharge of Lake Algonquin into the Mattawa river east of Lake Nipissing.

GOLDTHWAIT, J. W.:—

'Correlation of the raised beaches on the west side of Lake Michigan'; Jour. Geology, vol. 14, 1906, pp. 411-424.

Briefly outlines the results of a detailed study of the Algonquin and lower beaches in eastern Wisconsin; illustrates the usefulness of precise measurements of altitude of raised beaches by a profile of water planes; discusses the significance of these planes; correlates the 'Algonquin' and 'Nipissing' shorelines in the Lake Michigan basin with two horizontal beaches previously assigned to a local 'Lake Chicago.'

'Abandoned shorelines of eastern Wisconsin'; Bull. Wisconsin Geol. and Nat. History Survey, vol. 17, 1907, 134 pp., 37 plates, 37 figures.

Reviews the history of Lakes Chicago, Algonquin, and the Nipissing Great Lakes; discusses the work of many investigators in the field (*e.g.*, on pp. 18-22, J. W. Spencer's work in Ontario; on pp. 23-37, F. B. Taylor's studies in the United States and Canada); describes in detail the Algonquin, Nipissing, and other shorelines of eastern Wisconsin; reconstructs the warped water planes in the form of a profile; considers possible nature of the differential uplifts thus shown.

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Presents the results of wye-level surveys of beaches of Lakes Chicago, Algonquin, and Nipissing, in Michigan; also a detailed profile of these water planes, a detailed isobase map of the Algonquin beach over the northern part of Lake Michigan, and a general isobase map of that beach wherein data from Wisconsin and Michigan are correlated with Spencer's data from Ontario; discusses the significance of the fan-like profile of water-planes.

'The attitude of the Algonquin beach, and its significance'; (abstract) 'Science,' new series, vol. 28, Sept. 18, 1908, pp. 382-383.

Discusses the southward flattening of the Algonquin water plane over Lakes Michigan and Huron, and the use of the horizontal portion of this plane as a datum from which to estimate the amount of post-Algonquin uplift at places farther north.

'Preliminary report on measurements of altitude of the Algonquin and Nipissing shorelines in Ontario, July 6–August 11, 1908'; Can. Geol. Survey, Summary Rept., 1908, pp. 112-114.

Gives in outline some of the data which are presented in detail in the present report; and points out a few of the conclusions reached.

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'The Algonquin shoreline in Simcoe county, Ontario'; Can. Geol. Survey, Summary Rept. for 1902, pp. 281-304.

Describes in detail the raised beaches and other surface features of Simcoe county, and seeks an explanation of a supposed discontinuity and variability in height of the Algonquin and other shorelines.

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'Geology of Canada'; Rept. of Progress of Can. Geol. Survey to 1863, pp. 983.

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DEPARTMENT OF MINES

GEOLOGICAL SURVEY BRANCH

Hon. W. Templeman, Minister; A. P. Low, Deputy Minister;
R. W. Brock, Director.

SELECTED LIST OF REPORTS AND MAPS

(SINCE 1885)

OF SPECIAL ECONOMIC INTEREST

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572	" "	1893-4.	928	" "	1904.
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*854. Asbestos.
857. Infusorial Earth.
858. Manganese.
859. Salt.
No. 860. Zinc.
869. Mica.
872. Molybdenum and Tungsten.
*877. Graphite.
880. Peat.
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882. Copper.
913. Mineral Pigments.
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984. Mineral Pigments (French).

Reports of the Section of Chemistry and Mineralogy:—

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126	" 1877-8.	273	" 1887-8.	695	" 1898.
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148	" 1879-80.	333	" 1890-1.	821	" 1900.
156	" 1880-1-2.	359	" 1892-3.	*958	" 1906.

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GENERAL.

745. Altitudes of Canada, by J. White. 1899.
*972. Descriptive Catalogue of Minerals and Rocks, by R. A. A. Johnston and G. A. Young.
1073. Catalogue of Publications: Reports and Maps (1843-1909).
1085. Descriptive Sketch of the Geology and Economic Minerals of Canada, by G. A. Young, and Introductory by R. W. Brock. Maps No. 1084; No. 1042 (second edition), scale 100 m. = 1 in.
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